3.1. SOILS

SCOPE OF THE ANALYSIS

The scope of the analysis for soils, including landslide risk, includes the American River and Crooked River watersheds. Each of the two watersheds will be addressed separately.

The temporal bounds for soil and displacement effects are 70 years or more based on recovery curves developed on the Payette National Forest (Froelich et al., 1985), Geist et al., 1989 as cited in Page-Dumroese, 1993, and pre-project monitoring completed in 2002 for the Meadow Face Stewardship project and the Red River Watershed Assessment (USDA FS, 2003). Results from this field monitoring indicate little recovery over 30 to 50 years.

Soil erosion may decline to negligible within five years on burned and harvested areas. Mass wasting is considered to affect soil productivity for 20 years or more, until soil organic matter accumulates and colluvium fills in channels scoured by debris torrents.

Temporal bounds for potassium effects are indefinite since rates of geologic input of potassium are very slow in Belt-age metamorphic rocks susceptible to potassium loss.

Temporal bounds for road-related effects are indefinite, because roads may continue to erode and produce sediment throughout their life.

Temporal bounds for large woody debris effects are 172 to 573 years, the time needed to develop a new stand, generate mortality in mature trees, and then see them fall and decay into soil wood (Harvey et al., 1987).

Soil productivity is the inherent capacity of a soil to support the growth of specified plants, plant communities, and soil biota. Soil also performs an important role in hydrologic function: the ability of the soil to absorb, store, and transmit water both vertically and horizontally. Elements selected and indicators to evaluate and compare the alternatives in regard to soil productivity are associated with soil physical, chemical, and biological properties.

SOIL PHYSICAL PROPERTIES

INDICATORS INCLUDE:

SOIL COMPACTION AND DISPLACEMENT

ACRES OF GROUND BASED LOGGING AND/OR MACHINE PILING ON SOILS HIGHLY SUSCEPTIBLE TO COMPACTION AND DISPLACEMENT (USDA FOREST SERVICE, 1987, PAGE-DUMROESE, 1993)

- Acres of system and temporary road construction

SURFACE AND SUBSTRATUM EROSION

- Acres of harvest on soils rated as high hazard for surface soil erosion (USDA Forest Service, 1987)
- Acres of road system or temporary road construction on soil substrata rated as high hazard for erosion (USDA Forest Service, 1987)

MASS EROSION

- Acres of harvest and road construction on terrain rated high for landslide hazard

COMPLIANCE WITH FOREST SOIL QUALITY STANDARDS

- Activity acres estimated to not meet current or amended Forest Plan standard number 2 upon completion of activities, including any mitigation and restoration

SOIL CHEMICAL AND BIOLOGICAL PROPERTIES

INDICATORS INCLUDE:

INDICATORS OF SOIL POTASSIUM AND NITROGEN LOSS

- Potassium - Acres of harvest with more than 50 percent crown removal on metamorphic rock types susceptible to potassium deficiency.
- Nitrogen – Acres of harvest with more than 50 percent crown removal on any rock type.

INDICATORS OF POTENTIAL LOSS OF LARGE WOOD

Acres of clearcut harvest and slash disposal

REGULATORY FRAMEWORK

The Multiple Use-Sustained Yield Act of 1960 directs the Forest Service to achieve and maintain outputs of various renewable resources in perpetuity without permanent impairment of the land's productivity.

Section 6 of the National Forest Management Act of 1976 charges the Secretary of Agriculture with ensuring research and continuous monitoring of each management system to safeguard the land's productivity.

The Code of Regulations for Forest Planning (36 CFR 200.1, 1987) requires the Forest Service to measure effects of prescriptions, including "significant changes in land productivity". To comply with requirements, the Chief of the Forest Service charged each Forest Service Region to develop soil quality standards for detecting soil disturbances indicating a loss in long-term productive potential. These standards are built into Forest Plans and into Regional Soil Quality Guidelines.

The Nez Perce Forest Plan directs us to manage soil and water resources at levels designed to meet Forest management objectives for watersheds. The delineation, management, and protection of landslide prone areas and wetland soils are addressed in Forest Plan Amendment 20 (PACFISH). "Best management practices" shall be applied to all land-disturbing activities, including prevention of soil erosion during land management activities. The Plan additionally directs that we manage the soil resource such that the potential for soil productivity is maintained through the following standards:

1. Evaluate the potential for compaction, puddling, mass wasting, and soil erosion for all ground-disturbing activities,
2. Ensure that a minimum of 80 percent of an activity area (*such as a timber harvest unit*) is not detrimentally compacted, displaced, or puddled upon completion of activities
3. Maintain sufficient ground cover to minimize rill erosion and sloughing on road cut and fill slopes and sheet erosion on other activity areas (Nez Perce Forest Plan II-22).

Regional Soil Quality Guidelines (USDS FS, 1999) direct us to manage National Forest System lands without permanent impairment of land productivity and to maintain or improve soil quality.

For the two watershed project areas, the Forest Plan soil standards will apply without amendment. Any harvest unit found to exceed the 20 percent detrimental disturbance threshold from past human-caused activities will not be entered, unless additional impacts do not result in any increase in area of detrimental disturbance. Where past human-caused activities have resulted in detrimental disturbance below 20 percent, cumulative impacts upon completion of activities proposed for this project must not exceed 20 percent.

Detrimental disturbance is defined as a 15 percent increase in natural bulk density, wheel ruts at least 2 inches deep in wet soils, removal of 1 or more inches depth of any surface soil horizon, from a continuous area greater than 100 square feet, high intensity burns of long duration that alter soil physical and biological properties, and rills, gullies, pedestals and soil deposition indicative of detrimental surface erosion (USDA FS, 1999).

Analysis Methods

Baseline conditions and ecosystem processes are derived from ecological land unit mapping and limited field reconnaissance. Soil susceptibility to compaction, displacement, and erosion was inferred from soil survey map units (USDA FS, 1987), and field reconnaissance for this project.

Soil compaction and displacement was inferred from areas that have been tractor logged and dozer piled, as documented in the Timber Stand Management Record System, and through photo interpretation or field reconnaissance. The linkage between tractor operation, machine piling, and soil compaction, displacement, and soil productivity is established through scientific research (Cullen et al., 1991, Froelich et al., 1983) and Forest monitoring (USDA FS, 1988b, 1990, 1992, 1999 and 2003D).

Sensitivity to soil potassium and nitrogen loss was estimated using the work of Garrison and Moore, 1998.

Susceptibility to mass wasting was estimated using forest protocols described in (USDA FS reports on file at Forest Headquarters, 1996 and 2002).

3.1.1. American River

Existing Condition – American River

Introduction

The South Fork Clearwater River Landscape Assessment (USDA FS, 1998) identifies "Restore aquatic processes" as the area theme for the American River watershed within which the project area occurs. The priority is high for American River. Restoration is to include both restoration of aquatic conditions and processes in the watershed and adjustments to the road and trail system to support aquatic restoration and provide for administrative and public uses and maintain wildlife security. Soil resource management affects aquatic processes primarily through erosion, mass wasting, and soil compaction or disturbance that affects subsurface slope hydrology.

Geology, Soil Development, and Landforms

Rocks weather to form soil parent material; and soil texture, chemistry, and resistance to erosion are highly conditioned by geology.

Metamorphic rocks or their derivatives comprise 97 percent of the rock types in the watershed. Belt-age metamorphic rocks: gneiss, schist, and quartzite, weather to sandy loam, loamy sand, or sand parent materials and develop into soil parent materials that are rated moderate to high for substratum erosion hazard (USDA FS, 1987). Tertiary sediments and other alluvium are important in the American River Township, and are stratified sediments derived from the same geologic materials. They typically weather into soil parent materials that are rated moderate to high for substratum erosion hazard (USDA FS, 1987). These materials typically have low levels of inherent nutrients, and moderate to poor ability to retain nutrients (Garrison and Moore, 1998). Potassium deficiencies noted in these rock types can affect tree growth and susceptibility to root disease.

Granitics comprise about 3 percent of the project area. They are higher in certain nutrients, including potassium, but weather to sandy soils with low ability to retain nutrients. They typically weather into soil parent materials that are rated high to very high for substratum erosion hazard (USDA FS, 1987).

Most soils in the project area have surface layers formed in volcanic ash-influenced loess derived from the eruption of Mt. Mazama about 6700 years ago. This material is physically highly favorable to root growth, being very permeable and with a high ability to hold moisture and nutrients. This material is very easy to compact or displace at any moisture content (Page-Dumroese, 1993), and is essentially irreplaceable without volcanic additions.

Soil response to disturbance depends not only on soil type, but topographic setting and slope hydrology. Landforms have characteristic slope shape, steepness, and stream dissection, which affect erosion and sediment delivery to streams.

- Rolling hills of low to moderate relief dominate the watershed at lower and mid elevations (80 percent of the watershed). The volcanic ash influenced soil surface layers buffer against erosion except where soil substrata are exposed, as in roads or mines. Substratum erosion hazard is moderate to high. Slopes are gentle to moderate and sediment is delivered to streams with moderate efficiency. Unstable slopes are uncommon, and typically occur as small areas on lower slopes or near stream headlands. West and south facing slopes at low elevation may have thin or mixed ash surface layers. These soils do not hold moisture as well as ash-influenced soils and are more liable to surface erosion.
- Stream breaklands and steep mountain slopes are of limited extent in the watershed (8 percent). In comparison to rolling hills, breaklands have steep slopes, shallower soils, thin or mixed loess surface layers, higher surface erosion risk, higher risk of mass failure, and more rapid delivery of sediment to streams. Debris torrents can occur in headwater channels after intense rainstorms or rain-on-snow events.
- Convex slopes are found at upper elevations (5 percent of the area). In comparison to rolling hills, convex slopes have broader ridges, lower drainage density, and bedrock is usually deeply fractured. Volcanic ash surface layers are typically present and buffer against surface erosion. Substratum erosion hazard is high. Slopes are gentle to moderate and sediment is delivered to streams with low efficiency. Unstable slopes are uncommon, and typically occur as small areas on lower slopes or near stream headlands.
- Alluvial valleys form along low gradient stream channels (3 percent of the watershed). Soils are often poorly drained and subject to water transport most of the year. Substrata are coarse sands with gravel and cobble. Some have been dredge mined and only coarse mine spoils remain. Sediment delivery efficiency is very high (USDA FS, 1987); most of this landform is a riparian area.

EXISTING CONDITION – AMERICAN RIVER: SOIL PHYSICAL PROPERTIES

SOIL COMPACTION AND DISPLACEMENT

Road building, mining, tractor logging, and machine piling have heavily impacted soils in American River.

Mining effects have been localized but severe: soils in dredge and placer-mined areas have been removed, and sterile tailing piles remain. Soil recovery has been very slow and some of these areas still act as sediment sources. A minimum of 307 acres of this condition occurs in the analysis area.

About 11,314 acres (19 percent of the watershed) have been tractor logged and/or machine piled resulting in soil compaction and displacement over some of that area. Where the volcanic ash surface layer is compacted, displaced or mixed, soil moisture holding capacity is significantly impaired (USDA FS, 1999b). Harvest units that were tractor logged and dozer piled average 52 percent of the activity area damaged in the adjacent Red River watershed (USDA FS, 2003), which has similar landforms and soils. Units that were tractor logged and broadcast burned in that watershed averaged 38 percent damaged (USDA Forest Service, 2003). Units that were tractor logged, but not dozer piled or scarified, sustained 12-42 percent damage. Other monitoring data indicate 15-25 percent damage for this tractor logging without machine piling (USDA Forest Service, 1990 and 1991). Excavator piling has been documented on 250 acres in American River. This is usually less impactive than dozer piling, but can still sometimes result in more than 20 percent detrimental disturbance. An estimate of total soil damage from ground-based logging is 35 percent of the total area tractor logged, or 3960 acres.

About 778 acres of cable yarding have occurred in American River. Soil damage is usually confined to yarding corridors and landings, and accounts for about 4 percent of the activity area, based on monitoring in other areas (USDA FS, 2003).

Road construction also displaces soil, with long-term to permanent impairment of soil productivity. About 860 acres of documented system roads occur where topsoil and subsoil have been displaced, mixed, or lost to erosion. This represents about 1.5 percent of the analysis area. Additional undocumented non-system roads occur in the Elk City Township.

Motorized and non-motorized trails account for an estimated 65 acres of soil disturbance. Soils are both compacted and displaced. Numerous undocumented user-created ATV trails exist, which add to the amount of detrimental disturbance in the project area.

<u>SURFACE AND SUBSTRATUM EROSION</u>

Past mining has caused locally severe erosion of both surface soil and substrata, often concentrated in valleys where eroded material can reach streams: American River, Little and Big Elk Creeks, and Buffalo Gulch (USDA FS, 1998). A minimum of 307 acres has been affected by dredge mining. Other upland mine sediment sources also exist, where soils have been displaced.

Past fires have resulted in locally severe surface erosion, but post-fire erosion typically declines to negligible with vegetation recovery in about 4 years (Megahan, cited in USDA FS, 1981, and Elliot and Robichaud and Brown, 1999 as shown in Elliot and Robichaud, 2001). The most recent large fire occurred in 1919 in the watershed. This fire burned about 24,000 acres or 41 percent of the watershed. This was also the largest documented fire in American River. Other large fires burned in 1878, 1889, and 1910. Human ignitions may have been a factor in these fires, but 1889, 1910, and 1919 were severe fire years throughout the region (Barrett et al., 1997).

Surface erosion from timber harvest has been slight. The volcanic ash-influenced surface soil is rated as low surface erosion hazard (USDA FS, 1987) and occurs over more than 75 percent of the project area. Excavated skid trails and temporary roads are prone to erosion because the surface soil is removed. About 507 acres have been harvested in the past on soils with high surface erosion potential. These are on steep slopes, usually on south aspects, or in riparian areas where soil is readily detached and transported by water. Harvest has occurred on 510 acres on soils with moderate surface erosion hazard. They are usually on steep slopes on north aspects. Surface erosion on harvest units typically declines to negligible over time, except for some landings, excavated skid trails, and temporary roads that remain on the landscape (USDA FS, 1981).

Motorized and non-motorized trails account for 65 acres of soil disturbance, susceptible to surface and subsurface erosion. Thirty-five acres are on soil substrata rated high for erosion hazard. Numerous undocumented user-created ATV trails exist in addition to the system trails, and add disproportionately to the amount of erosion in the project area, because they may go straight up slopes or cross creeks, and have no erosion controls. They are often gullied or rutted.

Road building is the primary current source of erosion and sediment production in the project area. Forty-two percent of the watershed is rated high for substratum erosion hazard (USDA FS, 1987). About 251 acres of past road construction (about 63 miles) are on soil substrata that are rated high for erosion hazard Road erosion and sediment yield usually decline over time, but continue at a chronic level indefinitely (USDA FS 1981). Periodic large pulses of erosion may occur during intense or prolonged rainstorms or rain-on-snow events, or after burning or harvest that increases water yield and overland flow in interaction with road drainage systems (Wemple, 1994).

MASS EROSION

Mass erosion is the movement of large bodies of soil under the effect of gravity. Movement may be accelerated by high moisture levels, undercutting of toe slopes, or loss of tree rooting strength, among other factors (Chatwin et al., 1991). Landslides here include slumps, creep, debris avalanches or flows, debris torrents, and bedrock slides. Landslides can result in on-site loss of soil productivity, as surface soils are translocated down slope. Sediment delivered to streams may comprise fine sediments, which could have negative impacts, or larger rock and large organic debris, which could enhance stream habitat complexity.

Landslide hazard is low in most of the analysis area. About 362 acres (less than .6 percent of the analysis area) are mapped as high hazard for landslides. These are steep slopes, especially in concave headwalls, and features that show evidence of past mass wasting. Debris avalanche, debris torrent, and shallow slumps are the most likely kinds of mass failures in the area, but field reconnaissance indicates past mass wasting has been generally restricted to small scale-events with modest impacts. Tertiary sediments are common in the Elk City Township. These materials are prone to small slumps when saturated, especially road cut failures.

Road construction in such settings may precipitate road cut or fill failures, and occasionally loss of the road prism, or, by undercutting a toe slope, activate a landslide upslope. Only 1 acre of road construction and 33 acres of timber harvest have occurred on land rated high for landslide risk. No documented landslide response has occurred on these areas. During the flood episode of 1996-1997, no mass erosion was reported in the analysis area.

COMPLIANCE WITH FOREST AND REGIONAL SOIL QUALITY STANDARDS

Soil quality standards apply to activity areas other than the dedicated transportation system and administrative sites. This includes temporary roads, harvest units, mine sites, grazed areas, and burned areas. This discussion focuses on Forest Soil Standard number 2: a real extent of detrimental soil disturbance. Refer to the Legal Framework in the Soil Resource section.

About 95 percent of the American River watershed has soils rated highly susceptible to compaction or displacement (Page-Dumroese, 1993; USDA FS, 1987). About 11,621 acres have been tractor-logged or mined, or 20 percent of the analysis area. Most of this logging occurred from 1960-1989, but extensive clearing occurred during the mining era in the Township. American River is considered similar in soils and logging history to Red River. About 73 percent of all harvest activity areas have been logged with ground-based equipment. Assuming 80 percent of these would not meet forest Plan standards, (based on sampling in adjacent Red River watershed), 58 percent of all logging areas would not meet Forest Plan Soil quality standard 2: extent of detrimental soil disturbance on completion of activities. This degree of soil damage is consistent both with other

Forest monitoring (USDA FS 1988, 1990, 1992), and research (Krag, 1991; Froelich, 1978; Davis, 1990, Alexander and Poff, 1985).

Cable logging typically produces relatively little soil damage (research cited in Alexander and Poff, 1985). Two sampled cable-logging units in Red River averaged 4 percent detrimental disturbance. About 778 acres, about 1.3 percent of the American River, has been cable-logged.

Total area of impaired soil quality is estimated at 5223 acres in American River, or 8.9 percent of the watershed.

Existing condition – American River: Soil Chemical and Biological Properties

Soil potassium and nitrogen loss

The inherent rock nutrient status of the local metamorphic gneisses, schists, and quartzites in American River is rated as medium to poor (Garrison and Moore, 1998), but no sampling specific to the analysis area has been done. Their expected soil nutrient status is also medium to low (Buol et al., 1989). These rock types account for about 85 percent of the analysis area. Only 130 acres of YUM yarding (yarding unmerchantable material) or yarding of slash has been documented in the analysis area, on this geologic material. Much of this yarding may have been bole only, but tops and limbs may also have been removed. Removal of tops and limbs is likely to result in about twice as much potassium loss as bole-only yarding, so a few localized areas may have sustained potassium loss.

Granites are rated as having good inherent nutrient status, but medium to low soil nutrient status because of their poor capacity for nutrient retention. Granites account for about 3 percent of the analysis area. Alluvial deposits of mixed origin comprise the remainder.

Volcanic ash surface soils have high cation exchange capacity and good moisture storage capacity, but may not have high levels of available soil nutrients, including potassium (Stark and Spitzner, 1982).

Of the tree species likely to be removed, grand fir accumulates the highest foliar levels of potassium, so harvesting tops of this species is more likely to deplete soil potassium than harvesting lodgepole pine tops, which have the lowest levels of foliar potassium (Moore et al. 2004).

Soil nitrogen is typically limiting in all rock and soil types and whole tree yarding has similar or greater effects on soil nitrogen reservoirs (Shaw, 2003). Soil nitrogen can be replenished more rapidly through nitrogen fixation or atmospheric deposition than can potassium, which must weather from rocks.

About 8820 acres, or about 15 percent of the American river watershed, have been clearcut harvested with dozer piling or broadcast burning. Nitrogen losses have probably been substantial on these sites. Because slash disposal burns logs on the ground rather than standing trees, soil temperatures can be hotter and nitrogen loss by volatilization may therefore be greater than with a wildfire.

Loss of Soil Wood

Coarse woody debris (CWD) is woody material derived from tree limbs, boles, and roots in various stages of decay, here defined as that larger than 3 inches in diameter (Graham et al., 1994). Coarse woody debris protects the soil from erosion, contributes to wildlife and fisheries habitat, and moderates soil microclimate. Highly decayed CWD can hold more water than mineral soil, provides sites for nitrogen fixation, and releases nutrients through decay or burning. Highly decayed wood provides sites for ectomycorrhizal colonization, which contributes to plant growth and plays a role in the food chains of many small rodents and their predators.

Coarse woody debris in natural systems fluctuates with forest growth, mortality, fire, and decay. Harvest and slash burning can remove large wood to a degree that its soil function is impaired, since both standing boles and down wood may be much reduced.

About 8820 acres, or about 15 percent of the American River watershed, have been clearcut harvested with dozer piling or broadcast burning. Most of this harvest was prior to 1990, when the first large woody debris prescriptions might have been implemented. Field reconnaissance in the adjacent Red River watershed indicates large woody debris is deficient on such sites, in comparison to most natural disturbance regimes. In addition, very few green trees or snags were left on regeneration harvest units, so that very few trees are available for recruitment over the next 50-100 years.

Areas of old forest in moist habitats and areas of past mortality of lodgepole pine in the beetle outbreak of the 1980s may have heavy loads of CWD. They are not unnaturally high, but are susceptible to consumption by wildfire. Wildfire would consume some material and create dead standing timber, which would be recruited as large woody debris over time.

ENVIRONMENTAL EFFECTS

Indicators of direct environmental effects on soils are summarized in Table 3.1 below for American River

Table 3.1: Indicators of Direct Soil Effects by Alternative: American River

Activity	Alternative				
	A	B	C	D	E
Ground-based timber harvest on soils rated high for compaction or displacement hazard (acres) plus new temporary road construction (acres)	0	424	516	764	251
Timber harvest on soils rated high for surface erosion hazard (acres)	0	0	0	0	0
Road construction on soil substrata rated high for erosion hazard (acres)	0	4	7	7	2
Road construction or timber harvest on lands preliminarily mapped as high landslide hazard (acres)	0	0	0	0	0
More than 50 percent canopy removal on geologic materials potentially susceptible to potassium losses (acres)	0	494	583	824	281
More than 50 percent canopy removal that could contribute to nitrogen losses (acres)	0	542	631	872	293
More than 80 percent canopy removal and slash disposal with potential for high soil wood loss (acres)	0	291	356	356	75
Soil restoration (acres) on old harvest units (Most are associated with roads to be decommissioned)	0	5	8	9	21
Soil restoration through decommissioning of old road (acres)	0	24	32	37	81
Soil restoration through decommissioning of new temporary roads (acres)	0	14	32	32	8
Actual acres estimated to sustain detrimental impacts from the proposed actions using Regional Soil Quality definitions of detrimental disturbance (20 percent of ground based harvest, 4 percent of cable harvest and 100 percent of temporary road construction)	0	103	139	188	60

Table 3.2: Indicators of Cumulative Soil Effects by Alternative: American River

Activity	Existing Condition Plus Proposed and Foreseeable Actions[1]					
	A	B	C	D	E	Existing Condition
Ground-based timber harvest on soils rated high for compaction or displacement hazard, plus road construction or mining (acres)	13,649	14,073	14,165	14,413	13,900	12,546
Timber harvest or burn on soils rated high for surface erosion hazard (acres)	507	507	507	507	507	507
Road or trail construction on soil substrata rated high for erosion hazard (acres)	289	293	296	296	291	286
Road construction or harvest on lands preliminarily mapped as high landslide hazard (acres)	47	47	47	47	47	34
More than 50 percent canopy removal on geologic materials potentially susceptible to potassium losses (acres). Assumes whole tree yarding or YUM yarding of tops for FS project only.	130	624	713	954	411	130
More than 50 percent canopy removal that could contribute to nitrogen losses (acres). Assumes whole tree yarding or YUM yarding of tops for FS project only.	8820	9362	9451	9692	9113	8820
Clearcut timber harvest and slash disposal with potential for high soil wood loss	9135	9426	9491	9491	9210	8820
Soil restoration on old harvest units (acres). Most are spatially associated with roads to be decommissioned (acres)	0	5	8	9	21	0
Soil restoration through system road decommissioning, assuming road recontour	0	24	32	37	81	0
Actual acres estimated to have sustained detrimental impacts using Regional Soil Quality definitions of detrimental disturbance [2]	5559	5662	5698	5747	5619	5223

[1] A foreseeable action includes Eastside Township project

[2] Estimated conditions of past logging are based on acres tractor-logged multiplied by .35 (the average areal percent damage associated with such tractor logging), plus acres cable logged multiplied by .04 (the average areal damage associated with cable logging) plus documented areas of mine impacts, system roads, and trails.

Acres by alternative for the American Crooked River project are estimated using the same assumptions except that the percent damage for tractor-logged areas would be held at the Forest threshold (.20).

3.1.1.1. Indicator 1 – Soil Physical Properties

Soil compaction and displacement

Alternative A – no action alternative

Direct

Under the **no action Alternative A**, no soil compaction or displacement would occur as a consequence of road construction, timber harvest, or fuel reduction activities. Existing soil compaction and displacement would persist with very slight natural recovery of surface layers of compacted soils. No soil restoration or watershed improvement activities would occur, so the long-term upward trend would be slow.

If a wildfire occurred, mechanized suppression activities and subsequent salvage logging could create severe soil impacts, depending on fire characteristics and administrative decisions. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition and burning weather. Because the location, intensity, and size of future fire, or agency actions in response to fire, are uncertain, with or without implementing any action alternative, the evaluation of alternatives by fire hazard is most appropriately addressed in the Fire section.

The continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe fire effects on soil, including physical alteration of soil structure and development of hydrophobic layers, but compaction and displacement from a potential natural wildfire are not likely.

Alternative B

Direct

Alternative B would result in soil impacts less than Alternatives C and D, but more than Alternative E. Under Alternative B, 410 acres of timber harvest or mechanical fuel reduction would occur using ground-based logging systems on soils highly subject to compaction and displacement and 14 acres of new temporary road construction. Assuming that compaction and displacement can be held to within the 20 percent areal disturbance threshold of Forest Plan Soil standard 2, 89 acres on harvest units would be detrimentally compacted or displaced, along with 14 acres on new temporary roads.

About 229 acres are proposed for possible roadside salvage of dead and at risk trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for soil disturbance is slight.

Soil restoration proposed in Alternative B is less than any other action alternative. Restoration on existing impacted sites (roads and units) would treat a total of about 29 acres. Existing soil compaction and displacement would be treated on units on an estimated five of these acres. Existing roads to be decommissioned account for another 24 of the 29 acres. Temporary roads built for this project would be decommissioned, for an additional 14 acres of restoration.

Alternative C

Direct

Alternative C would result in soil impacts less than Alternative D, but greater than other alternatives. Under Alternative C**,** 484 acres of timber harvest or mechanical fuel reduction would occur using ground-based logging systems on soils highly subject to compaction and displacement, along with 32 acres of new temporary road construction. Assuming that compaction and displacement can be held to within the 20 percent areal disturbance threshold of the Forest Plan Soil Standards, 107 acres on harvest units would be detrimentally compacted or displaced, and 32 acres on temporary roads.

About 227 acres are proposed for possible roadside salvage of dead and at risk trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for soil disturbance is slight.

Soil restoration proposed in Alternative C is slightly more than Alternative B, and less than alternatives D and E. Restoration on existing impacted sites (roads and units) would treat a total of about 40 acres. Existing soil compaction and displacement would be treated on units on an estimated eight of these acres. Existing roads to be decommissioned account for another 32 of the 40 acres. Temporary roads built for this project would be decommissioned, for an additional 32 acres of restoration.

ALTERNATIVE D

DIRECT

Alternative D would result in the greatest soil impacts of any alternative. Under Alternative D, 732 acres of timber harvest or mechanical fuel reduction would occur using ground-based logging systems on soils highly subject to compaction and displacement, along with 32 acres of new temporary roads. Assuming that compaction and displacement can be held to within the 20 percent areal disturbance threshold of the Forest Plan soil quality standard item 2, 156 acres on harvest units would be significantly compacted or displaced, along with 32 acres of temporary roads.

About 247 acres are proposed for possible roadside salvage of dead and at risk trees. This is more than other action alternatives. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for soil disturbance is slight.

Soil restoration proposed in Alternative D is slightly more than Alternatives B and C, and less than Alternative E. Restoration on existing impacted sites (roads and units) would treat a total of about 46 acres. Existing soil compaction and displacement would be treated on units on an estimated nine of these acres. Existing roads to be decommissioned account for another 37 of the 46 acres. Temporary roads built for this project would be decommissioned, for an additional 32 acres of restoration.

ALTERNATIVE E

DIRECT

Alternative E avoids soil impacts better than any other action alternative, through reduction in road construction and area of ground-based logging. Under Alternative E, 243 acres of timber harvest or mechanical fuel reduction would occur using ground-based logging systems on soils highly subject to compaction and displacement, along with 8 acres of new temporary roads. Assuming that compaction and displacement can be held to within the 20 percent areal disturbance threshold of the Forest Plan soil standard 2, 52 acres on harvest units would be detrimentally compacted or displaced, along with 8 acres of temporary roads.

About 217 acres are proposed for possible roadside salvage of dead and at risk trees. This is less than other action alternatives. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for soil disturbance is slight.

Alternative E proposes substantially more soil restoration than any other alternative. Restoration on existing impacted sites (roads and units) would treat a total of about 102 acres. Existing soil compaction and displacement would be treated on units on an estimated 21 of these acres. Existing roads to be decommissioned account for another 81 of the 102 acres. Temporary roads built for this project would be decommissioned, for an additional 8 acres of restoration.

ALL ALTERNATIVES

INDIRECT EFFECTS – ALL ALTERNATIVES

Indirect effects of soil compaction and displacement include effects to vegetation and hydrologic processes. Compaction and displacement can result in reduced moisture holding capacity, greater drought stress, and susceptibility to pathogens or fire. Certain species have a greater competitive advantage in disturbed soils, like weeds or lodgepole pine, so that shifts in plant community composition have been noted in field inventories of harvest units (USDA Forest Service, 2003c). Altered soil porosity and moisture holding capacity (USDA FS 2000) could contribute to higher drought stress, lower ground cover, and shifts in disturbance regimes like erosion or fire. The relative ranking of likely persistent indirect effects by alternative is (best to worst): A, E, B, C, and D.

IRREVERSIBLE OR IRRETRIEVABLE EFFECTS – ALL ALTERNATIVES

Soil compaction effects can last 70 years (Froelich et al., 1983), but are not irretrievable. Decompaction can at least partly restore soil porosity. Soil displacement that mixes or removes the volcanic ash surface layer reduces soil moisture holding capacity, which may be irreversible without volcanic additions. The relative ranking of likely persistent soil compaction and displacement by alternative is (best to worst): A, E, B, C, and D. Stockpiling and replacing topsoil could mitigate this loss for roads and landings, as well as other mitigation to minimize damage; see the discussion of project design measures and mitigation in the Conclusions section below.

CUMULATIVE EFFECTS – ALL ALTERNATIVES

Activities that cause soil compaction and displacement may have cumulative effects on soil porosity; water holding capacity, aeration, and long-term productivity, with repeated entries. Cumulative effects may also occur at the landscape level, where large areas of compacted and displaced soil affect vegetation dynamics, runoff, and water yield regimes. About 4849 acres are currently estimated to have sustained detrimental compaction or displacement in the American River watershed due to logging, mining, or road construction. The alternatives will add from 60 to 188 acres, depending on alternative, and the foreseeable Eastside Township project could add an estimated 271 acres due to harvest and road construction, for a total of about 1 percent of the watershed.

Rigorous mitigation and restoration may constrain these effects to current or slightly improved levels. Additional soil restoration associated with decommissioning of old roads and treating old harvest units will also reduce the extent of cumulative effects within the project area. Cumulative effects are directly related to the scope of timber harvest and mechanical fuel reduction activities, temporary road construction, and soil restoration. The relative ranking of likely cumulative effects by alternative is (best to worst): A, E, B, C, and D. Although Alternative A would not do any soil restoration, most restoration is not completely successful in areas of thin volcanic ash surface soils, so avoidance more successfully conserves soil productivity.

SURFACE AND SUBSTRATUM EROSION

EXISTING CONDITION AND ENVIRONMENTAL EFFECTS

ALTERNATIVE A – NO ACTION ALTERNATIVE

DIRECT EFFECTS

Under the **no-action Alternative A**, surface and substratum erosion processes would continue on roads, skid trails, and landings with slight abatement as slow natural vegetation recovery occurs. Erosion from harvest units would continue to decline to negligible. No new management sources of surface or substratum erosion would occur, so the net trend would be reduced management-derived erosion. However, no soil or watershed improvement activities would occur, so the long-term upward trend would be slow.

If a wildfire occur, consequent surface soil erosion would range from negligible to severe, depending on location, size and severity of burn, soil disturbance associated with suppression, salvage logging, or burn rehabilitation activities, and interaction of watershed response with the existing transportation system. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition and burning weather.

The continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe burning behavior, which can increase the likelihood of surface erosion, but this may be similar to risks associated with logging and broadcast burning on areas proposed for treatment. Sediment modeling assumptions derived from research (USDA FS 1981) suggest that erosion from tractor logging on gentle to moderate slopes would be slightly less than a severe fire on a steep slope, cumulatively over a 5-year time span, not considering the additional substratum erosion from harvest access roads. Alternative evaluation would depend on the reduction of wildfire size and severity in untreated areas. Refer to the discussion of fire hazard in the Fire management section.

ALTERNATIVE B

DIRECT

Alternative B would result in little surface erosion and less substratum erosion than Alternatives C and D, but more than Alternatives A and E. Under Alternative B, no timber harvest or fuel reduction would occur on soils highly susceptible to surface erosion.

About 229 acres are proposed for possible roadside salvage of dead and at risk trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential exposure to soil erosion is slight.

An estimated 4 acres of temporary road construction on soil substrata highly susceptible to erosion are proposed for Alternative B. Road construction is more likely to result in erosion than harvest.

The 43 acres of soil restoration described under soil compaction and displacement would reduce surface and substratum erosion problems on some existing sites, particularly on steep skid trails, poorly vegetated landings, and existing temporary roads.

ALTERNATIVE C

DIRECT

Alternative C would result in little surface erosion and similar substratum erosion to Alternative D, but more substratum erosion than Alternatives A, B and E. Under Alternative C, no timber harvest or fuel reduction would occur on soils highly susceptible to surface erosion.

About 227 acres are proposed for possible roadside salvage of dead and at risk trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential exposure to soil erosion is slight.

An estimated 7 acres of temporary road construction on soil substrata highly susceptible to erosion are proposed for Alternative C. Road construction is usually more likely to result in erosion than harvest.

The 72 acres of soil restoration described under soil compaction and displacement would reduce surface and substratum erosion problems on some existing sites, particularly on steep skid trails, poorly vegetated landings, and existing temporary roads.

ALTERNATIVE D

DIRECT

Alternative D would result in little surface erosion but similar substratum erosion to Alternative C, but more substratum erosion than Alternatives A, B and E. Under Alternative D, no timber harvest or mechanical fuel reduction would occur on soils highly susceptible to surface erosion.

About 247 acres are proposed for possible roadside salvage of dead and at risk trees. This is more than any other action alternative. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential exposure to soil erosion is slight.

An estimated 7 acres of temporary road construction on soil substrata highly susceptible to erosion are proposed for Alternative D. Road construction is usually more likely to result in erosion than harvest.

The 78 acres of soil restoration described under soil compaction and displacement would reduce surface and substratum erosion problems on some existing sites, particularly on steep skid trails, poorly vegetated landings, and existing temporary roads.

ALTERNATIVE E

DIRECT

Alternative E would result in little surface erosion and less substratum erosion than the other action alternatives. Alternative E would also address more soil restoration that could reduce existing erosion. Under Alternative E, no timber harvest or fuel reduction would occur on soils highly susceptible to surface erosion.

About 217 acres are proposed for possible roadside salvage of dead and at risk trees. This is less than any other action alternative. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential exposure to soil erosion is slight.

An estimated 2 acres of temporary road construction on soil substrata highly susceptible to erosion are proposed for Alternative E. Road construction is usually more likely to result in erosion than harvest.

The 110 acres of soil restoration described under soil compaction and displacement would reduce surface and substratum erosion problems on some existing sites, particularly on steep skid trails, poorly vegetated landings, and existing temporary roads.

ALL ALTERNATIVES

INDIRECT

Indirect effects of soil surface and substratum erosion include effects to vegetation and hydrologic processes. Surface erosion removes the soil materials with the greatest ability to hold moisture and nutrients, potentially resulting in greater drought stress, poorer growth, and susceptibility to pathogens or fire. Since volcanic ash is not easily replaced, these effects may be very long lasting. Certain species have a greater competitive advantage in eroded soils, like weeds or lodgepole pine, so that shifts in plant community composition and consequent disturbance regimes like erosion or fire, could occur. Eroded surface and substratum material may be delivered to streams and have consequences to water quality, stream temperature, quality of fish habitat, and channel morphology. See the Watershed and Fisheries discussions. The relative ranking of likely indirect effects by alternative is (best to worst): E, A, B, C and D.

IRREVERSIBLE OR IRRETRIEVABLE EFFECTS – ALL ALTERNATIVES

Eroded surface soil, where it is derived from volcanic ash influenced loess, is irretrievable without volcanic additions. Residual soil materials would develop into topsoil over several decades to hundreds of years, but this material may lack the moisture holding properties of volcanic ash.

The relative ranking of likely surface soil erosion by alternative is (best to worst): A, E, B, C, and D. Effects of eroded substratum material are not irretrievable or irreversible; although effects as delivered sediment may be long lasting.

CUMULATIVE EFFECTS (INCLUDES FORESEEABLE FUTURE ACTIONS)

Activities that result in soil surface and substratum erosion may have cumulative effects on water holding capacity, nutrient pools and retention, and long-term productivity, with repeated entries. Cumulative effects may also occur at the landscape level, where large areas of soil exposed to erosion affect vegetation dynamics, invasive species, runoff, and sediment regimes. Erosion of surface soils on old harvest units is expected to have declined to zero, but substratum erosion from roads continues on about 843 acres in the project area. The alternatives will add from 2 to 4 acres of road construction on soil substrata highly susceptible to erosion, and the foreseeable Eastside Township project about 3 acres of road construction on highly erodible substrata.

Rigorous mitigation and restoration may constrain these effects to current or slightly improved levels. Control of erosion is generally easier to attain than amelioration of displacement that results in loss of topsoil.

Past activities considered in cumulative effects are timber harvest and road construction on soils susceptible to erosion. Mining impacts on at least 307 acres are likely to have resulted in localized severe erosion. Some thinning and pruning have occurred around administrative structures as part of defensible space projects in the analysis area. This work is accomplished by hand, with little soil exposure or likelihood of erosion. Streamside cattle grazing has occurred in meadow complexes and resulted in stream bank failure and localized erosion.

With increasing activities in previously unimpacted areas, the potential scope of effects to on-site productivity, sediment delivery, water yield, and stream morphology increases. Cumulative effects are directly related to the scope of timber harvest and temporary road construction on susceptible soils, and the partial compensation offered by road decommissioning and soil restoration. The relative ranking of likely cumulative effects by alternative is (best to worst): A, E, B, C, and D.

MASS EROSION

ALTERNATIVE A – NO ACTION ALTERNATIVE

DIRECT

Under the **no-action alternative**, mass erosion processes would remain a slight factor in soil processes in the analysis area. Mass erosion from natural causes would continue at small scales and infrequent rates. Mass erosion from past management activities would continue at a very localized scale and declining rate as old roads stabilized and harvest units renegotiated. No new management sources of mass erosion would occur from these alternatives, so the net trend would be reduced management-derived mass erosion. However, no soil or watershed improvement activities would occur, so the long-term upward trend would be slow.

If a wildfire occurred, consequent mass erosion could range from negligible to modest, depending on location, size, and severity of burn, soil disturbance associated with suppression, salvage logging, or burn rehabilitation activities, and interaction of watershed response with the existing transportation system. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition and burning weather.

However, the continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe burning behavior, which can increase the likelihood of mass erosion in steep draws, drainage headlands, and on steep, wet lower slopes, because rooting strength would be lost, and more moisture available. These effects are similar to clearcut logging and broadcast burning. Alternative evaluation would depend on the reduction of wildfire size and severity in untreated areas, and in areas where partial canopy removal and underburn reduce likely wildfire severity. Refer to the discussion of fire hazard in the Fire section.

ALTERNATIVES B, C, D, AND E

DIRECT

Mass erosion would change little from natural rates under **Alternatives B, C, D, and E**. No harvest is proposed under any alternative on lands mapped as high risk for landslides. No temporary road construction is proposed on lands mapped as high risk. Design and mitigation measures address identification of localized areas of significant landslide risk, and adjustment of harvest prescriptions to maintain slope stability.

Soil restoration proposed on existing impacted sites can sometimes address existing mass erosion problems. Activities that include restoration of stream crossings and wetlands on roads, and recontouring roads and temporary roads can treat existing slope failure problems and reduce risk for future failures.

No roads proposed for decommissioning under any alternative in American River are on land mapped as high landslide hazard, but local road and slope failures would be identified and treated as roads are decommissioned. Alternative E offers the greatest potential to stabilize local mass erosion sites on roads to be decommissioned.

ALL ALTERNATIVES

INDIRECT EFFECTS – ALL ALTERNATIVES

Indirect effects of mass erosion include effects to vegetation and hydrologic processes. Mass erosion may affect surface or substratum materials. Mass erosion of surface soil removes the materials with the greatest ability to hold moisture and nutrients, potentially resulting in greater drought stress, poorer growth, and susceptibility to pathogens or fire. Since volcanic ash is not easily replaced, these effects may be very long lasting. Certain species have a greater competitive advantage in eroded soils, like weeds or lodgepole pine, so that shifts in plant community composition and consequent disturbance regimes, like erosion or fire, could occur. Typically mass erosion mixes surface and substratum materials so the unique properties of the surface soil are lost. Mass-eroded surface and substratum material may be delivered to streams and have consequences to water quality, stream temperature, quality of fish habitat, and channel morphology. See the watershed and fisheries discussions.

Indirect effects are likely to be minimal, and differences among alternatives slight, because of the low landslide hazard in American River. The relative ranking of potential indirect effects by alternative is (best to worst): A, E, B, C, and D.

Irreversible or Irretrievable Effects – All Alternatives

There are no irreversible or irretrievable direct effects of mass erosion, except for potential loss of volcanic ash-influenced topsoil. See the section of effects for surface erosion. Anticipated mass erosion processes under action or no-action alternatives are of slight probability, size, or effects, and are unlikely to exceed natural rates.

Cumulative Effects – All Alternatives

Activities that result in mass erosion are unlikely to have significant cumulative effects in the analysis area because of the low incidence of significant mass wasting hazard. Rigorous mitigation and restoration may improve the mass wasting condition by road decommissioning, while proposed road construction would be in low hazard locations.

The thinning and pruning that have occurred around administrative structures as part of defensible space projects in the analysis area will not increase mass wasting risk.

Foreseeable actions include 13 acres of timber harvest on lands preliminarily mapped as highly landslide prone as part of the Eastside Township project. No road construction is proposed for that project on lands mapped as high landslide hazard.

With increasing activities in previously unimpacted areas, the probability of a landslide is modestly increased, with some slight potential for effects to sediment delivery and temporary loss of on-site productivity in localized areas. Cumulative effects are directly related to the scope of past, proposed and foreseeable fuel reduction activities and temporary road construction in susceptible terrain. The relative ranking of likely cumulative effects by alternative is (best to worst): A, E, B, C, and D.

Compliance with Forest and Regional Soil Quality Standards

Alternative A – No Action Alternative

Direct

Under the **no-action Alternative A** the existing condition for compliance with Soil Quality Standards would continue, with slight amelioration as slow natural recovery of compacted surface soil occurred and surface soil development in disturbed areas occurred. Landings, temporary roads, and compacted or excavated skid trails would not recover enough within the temporal bounds of this analysis to meet standards.

No additional lands would be subject to temporary road construction or fuel reduction that would result in soil conditions not in compliance with standards from any of the action alternatives.

However, no soil or watershed improvement activities would occur that might accelerate soil recovery, so the long-term upward trend would be slower in untreated soil restoration areas, than with soil restoration.

If a wildfire occurred, consequent damage to soil conditions from suppression activities, burn severity, or salvage logging could range from negligible to severe, depending on location, size, and severity of burn and subsequent administrative activities.

The continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe burning behavior, but whether this might result in greater or more lasting soil damage than road construction or ground-based logging operations is uncertain. Wildfire seldom results in compaction or displacement, but could result in ground cover loss and erosion that exceeds Forest Plan standards or Regional Guidelines. Evaluation of alternatives depends on being able to compare fire size, location, and severity in untreated areas. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition and burning weather. See the discussion of fire hazard in the Fire management section

ALTERNATIVES B, C, D, and E

DIRECT

Under **Alternatives B, C, D, and E**, the areas proposed for ground-based timber harvest or mechanical fuel reduction on soils highly susceptible to compaction or displacement, are the areas most vulnerable to exceeding Forest Plan soil standard number 2, for areal extent of soil disturbance upon completion of activities. The areas proposed for such harvest have no recorded history of harvest or mechanical disturbance in the past, and no evidence of disturbance from aerial photo inspection, and reconnaissance field sampling, and are expected to fully meet either Forest Plan Standards or Regional guidelines at this time.

Project design and mitigation measures are proposed that constrain equipment type, timing of operation, location and density of skid trails, and restoration of mechanically disturbed areas, with the objective of ensuring that activity areas meet Forest Plan soil standard number 2, upon completion of proposed activities. These would apply to all alternatives. Because meeting this soil standard is difficult, the relative likelihood of meeting this standard for all activity areas is greater for alternatives that treat fewer areas. The relative ranking of alternatives for likelihood of complying with this soil standard is (from greatest likelihood of full compliance to least): A, E, B, C, and D.

Additional soil restoration is proposed under Alternatives, B, C, D, and E. Recovery of soil physical properties is not expected to be complete on all treated acres, but will establish an upward trend for soil conditions on the treated sites. Activities include decompaction, recontouring, addition of organic matter, weed control, and revegetation to restore compacted and displaced soils on main skid trails, existing temporary roads, landings, and newly constructed temporary roads. The relative ranking of alternatives for soil restoration activities is (greatest to least restoration): E, D, C, B, and A.

ALL ALTERNATIVES

INDIRECT EFFECTS – ALL ALTERNATIVES

Compaction and soil displacement can affect sediment delivery and water yield that have downstream consequences to water quality and fisheries habitat. Indirect effects to ecological processes include altered plant community establishment, growth and yield, changed competitive advantages to different species, heightened susceptibility to pathogens, drought and fire. Restoration can compensate for some effects, but recovery of full function may not occur in all cases. Based on the feasibility of effecting partial recovery on 1 to 2 percent of areas with past impacts, while incurring 15-20 percent impacts on new activity areas, the relative ranking of likely indirect effects by alternative is (best to worst): A, E, B, C, and D.

IRREVERSIBLE OR IRRETRIEVABLE EFFECTS – ALL ALTERNATIVES

Soil quality standards address issues of long-term productivity, so failure to comply with these standards implies long-lasting impairment of soil functions, if not irreversible or irretrievable effects. The effects of soil displacement and surface soil erosion are least reversible, and most irretrievable, since the volcanic ash surface material is hard to replace. See the sections on compaction and displacement. The relative ranking by alternative for these issues is (best to worst): A, E, B, C, and D.

CUMULATIVE EFFECTS – ALL ALTERNATIVES

Activities that cause compaction, displacement, or exposure to erosion, may have cumulative effects on belowground physical and biological processes, hydrologic function, and long-term productivity, especially in the case of repeated entries. Rigorous mitigation and restoration may meet Soil Quality Standards.

Past activities considered in cumulative effects are timber harvest, particularly ground-based logging and dozer piling, and documented mining impacts. Permanent roads are not considered in assessing compliance with soil quality standards. Some thinning and pruning have occurred around administrative structures as part of defensible space projects in the analysis area. This work is accomplished by hand so ground disturbance is minimal. Past fires are considered to be recovered and are not considered as cumulative effects.

All alternatives may meet Forest Plan soil quality standards if mitigation and design measures are rigorously applied, so that cumulative effects are the same for all alternatives on a site basis, but differ considered additively across the landscape, since temporary road construction may produce some degree of permanent impairment, even with decommissioning. From this perspective, the relative ranking of alternatives is (best to worst): A, E, B, C, and D.

3.1.1.2. INDICATOR 2 – SOIL CHEMICAL AND BIOLOGICAL PROPERTIES

SOIL POTASSIUM AND NITROGEN LOSS

ALTERNATIVE A – NO ACTION ALTERNATIVE

DIRECT

Under the **no-action Alternative A**, soil potassium and nitrogen would continue to cycle at current rates, and not be subject to removal through harvest or prescribed fire. Accrual would continue at low rates from rock weathering, atmospheric deposition, and nitrogen fixation. Soil nutrients would increasingly be bound in organic mater complexes and slowly released through decay. The net trend would be reduced management-derived nutrient loss. However, no soil or watershed improvement activities that might accelerate biological recovery on degraded sites would occur, so the long-term upward trend would be slower in untreated potential soil restoration areas.

If a wildfire occurred, consequent soil nutrient loss could range from negligible to severe, depending on location, size, and severity of burn, loss through salvage logging, and loss of nutrients through erosion or leaching. Fire could also make more nutrients readily available for plant uptake and benefit pot-fire plan growth. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition and burning weather.

The continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe burning behavior, which can increase the likelihood of nutrient loss to volatilization, erosion, or leaching. However, whole-tree yarding, hot broadcast burns, or hot burns of machine-piled slash could have equal effects because of the removal of material from the site. Concentration of slash in piles may result in losses due to hotter fires or significant reduction of nutrients from large areas. Alternative evaluation would depend on the reduction of wildfire size and severity in untreated areas, and in areas where partial canopy removal and underburn reduce likely wildfire severity. Refer to the discussion of fire hazard in the Fire section.

ALTERNATIVE B

DIRECT

Potential for potassium loss is less in **Alternative B** than Alternatives C or D, but more than Alternative E. Under Alternative B, potassium levels could potentially be detrimentally reduced on about 494 acres, where more than 50 percent canopy removal has been prescribed on potentially susceptible geologic materials. Where lodgepole pine comprises most of this removal (about 243 acres of clearcut harvest), potassium loss may be less because this species does not sequester as much potassium as other species. If the material is dead as well, needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, potassium losses could also be minimized.

About 229 acres are proposed for possible roadside salvage of dead and at risk trees. Extent and intensity of tree removal would be low and tops and limbs would be left in the woods so potential for nutrient loss is slight.

Potential for nitrogen loss is also less in Alternative B than Alternatives C or D, but more than E. Nitrogen levels would be reduced through timber harvest or mechanical fuel reduction, on 542 acres where percent canopy removal would be more than 50 percent. Where dead lodgepole pine comprises most of this removal (perhaps as much as 291 acres of clearcut harvest), nitrogen loss may be less because needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, nitrogen losses could also be minimized.

The 29 acres of soil restoration described under soil compaction and displacement would improve potential for nitrogen accretion and retention by accelerating soil stabilization and organic matter development.

ALTERNATIVE C

DIRECT

Potential for potassium loss is less for **Alternative C** than Alternative D, but more than Alternatives B and E. Under Alternatives C and D, potassium levels could potentially be detrimentally reduced on about 583 acres, where more than 50 percent canopy removal has been prescribed on potentially susceptible geologic materials. Where lodgepole pine comprises most of this removal (about 307 acres of clearcut harvest), potassium loss may be less because this species does not sequester as much potassium as other species. Where the lodgepole is dead as well, needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, potassium losses could also be minimized.

About 227 acres are proposed for possible roadside salvage of dead and at risk trees. Extent and intensity of tree removal would be low and tops and limbs would be left in the woods so potential for nutrient loss is slight.

Potential for nitrogen loss is less for Alternative C than Alternative D, but more than Alternatives B and E. Nitrogen levels would be reduced through timber harvest or mechanical fuel reduction, on 631 acres where percent canopy removal is more than 50 percent. Where dead lodgepole comprises most of this removal (as much as 356 acres of clearcut harvest), nitrogen loss may be less because needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, nitrogen losses could also be minimized.

The 40 acres of soil restoration described under soil compaction and displacement would improve potential for nitrogen accretion and retention by accelerating soil stabilization and organic matter development.

ALTERNATIVE D

DIRECT

Potential for potassium loss is greatest for **Alternative D**. Under Alternative D, potassium levels could potentially be detrimentally reduced on about 824 acres, where more than 50 percent canopy removal has been prescribed on potentially susceptible geologic materials. Where lodgepole pine comprises most of this removal (about 356 acres of clearcut harvest), potassium loss may be less because this species does not sequester as much potassium as other species. Where the lodgepole is dead as well, needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, potassium losses could also be minimized.

About 247 acres are proposed for possible roadside salvage of dead and at risk trees. Extent and intensity of tree removal would be low and tops and limbs would be left in the woods so potential for nutrient loss is slight.

Potential for nitrogen loss is greatest for Alternative D. Nitrogen levels would be reduced through timber harvest or mechanical fuel reduction, on 872 acres where percent canopy removal is more than 50 percent. Where dead lodgepole comprises most of this removal (as much as 356 acres of clearcut harvest), nitrogen loss may be less because needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, nitrogen losses could also be minimized.

The 46 acres of soil restoration described under soil compaction and displacement would improve potential for nitrogen accretion and retention by accelerating soil stabilization and organic matter development.

ALTERNATIVE E

DIRECT

Potential for potassium loss is least for Alternative E, compared to other action alternatives. Under Alternative E, potassium levels could potentially be detrimentally reduced on about 281 acres, where more than 50 percent canopy removal has been prescribed on potentially susceptible geologic materials. Where lodgepole pine comprises most of this removal (about 64 acres of clearcut harvest), potassium loss may be less because this species does not sequester as much potassium as other species. Where the lodgepole is dead as well, needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, potassium losses could also be minimized.

About 217 acres are proposed for possible roadside salvage of dead and at risk trees. Extent and intensity of tree removal would be low and tops and limbs would be left in the woods so potential for nutrient loss is slight.

Potential for nitrogen loss is least for Alternative E, compared to other action alternatives. Nitrogen levels would be reduced through harvest or prescribed fire, on 293 acres where percent canopy removal is more than 50 percent. Where dead lodgepole comprises most of this removal (as much as 75 acres of clearcut harvest) nitrogen loss may be less because needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, nitrogen losses could also be minimized.

The 102 acres of soil restoration described under soil compaction and displacement would improve potential for nitrogen accretion and retention by accelerating soil stabilization and organic matter development.

Indirect Effects – Soil Nitrogen and Potassium Loss

Indirect effects of soil wood loss include altered processes of forest regeneration and growth, favoring species requiring lower soil moisture, lower nutrient levels and greater tolerance for potential soil erosion. Indirect effects could also include loss of habitat for species requiring soil wood as dens or substrate for invertebrates, bacteria and fungi, which affect food availability for small rodents and their predators. The relative ranking of likely indirect effects by alternative is (best to worst): A, E, B, C, and D. Wildfire could affect any alternative by resulting in volatilization erosion loss of nutrients, but also by making more nutrients readily available for plant uptake.

Irreversible or Irretrievable Effects – Soil Potassium and Nitrogen Loss

There are no irreversible or irretrievable direct effects of nutrient loss, except for potential loss of potassium. Recovery of soil potassium depends on slow inputs from rock weathering and may represent an irretrievable loss in the case of whole tree yarding of green trees, especially grand fir, or hot broadcast burns on clearcuts, on susceptible geologic substrata. The actual potassium status of these rock types has not been locally assessed. Nitrogen is replenished more rapidly through biotic and abiotic fixation, but may also have long-lasting effects. The relative ranking of likely potassium and nitrogen loss by alternative is (best to worst): A, E, B, C, and D. Though not proposed with this action, the loss of certain soil nutrients, including nitrogen and potassium could be mitigated through ground-based or aerial application of common fertilizers.

Cumulative Effects - Soil Potassium and Nitrogen Loss

Activities that cause soil potassium and nitrogen loss may have cumulative effects on soil productivity, plant growth and yield, susceptibility to pathogens, and successional processes, with repeated entries. Past effects to potassium reserves due to management are not thought to be significant, because no entry into areas with prior timber harvest is proposed. Rigorous mitigation and restoration may constrain effects to current or slightly degraded levels for potassium, and little long-lasting effect for nitrogen.

Some thinning and pruning have occurred around administrative structures as part of defensible space projects in the analysis area. This work is accomplished by hand. Lower branches and small trees were generally removed, and either hand piled or burned. Localized potential for cumulative soil nutrient loss is possible, if treatment is continuously sustained.

Foreseeable actions include an estimated 1,261 acres of timber harvest or mechanical fuel reduction as part of the Eastside Township project. No whole tree yarding is proposed. Broadcast burning is proposed for slash disposal, which will keep more nutrients on site.

With increasing activities in previously unimpacted areas, the spatial extent of potential nutrient loss is increased, with possible effects to landscape composition, structure, and function. Cumulative effects are directly proportional to the scope of past, proposed and foreseeable regeneration timber harvest, particularly whole tree yarding, and likelihood for piling and burning slash that results in significant nutrient redistribution and volatilization. The relative ranking of likely cumulative effects by alternative is (best to worst) A, E, B, C, and D. Wildfire may result in significant potassium and nitrogen loss under any alternative, but may also result in greater net nutrient availability.

ALL ALTERNATIVES

INDIRECT EFFECTS – ALL ALTERNATIVES

Indirect ranking of likely indirect effects by alternative is (best to worst): A, E, B, C, and D. Wildfire could affect any alternative by resulting in volatilization, leaching, or erosion loss of nutrients, but also by making more nutrients readily available for plant uptake.

IRREVERSIBLE OR IRRETRIEVABLE EFFECTS – ALL ALTERNATIVES

There are no irreversible or irretrievable direct effects of nutrient loss, except for potential loss of potassium. Recovery of soil potassium depends on slow inputs from rock weathering and may represent an irretrievable loss in the case of whole tree yarding of green trees, especially grand fir, but may also have long-lasting effects. A possible mitigation measure beyond minimizing whole tree yarding is fertilization. The relative ranking of likely potassium and nitrogen loss by alternative is (best to worst): A, E, B, C, and D.

CUMULATIVE EFFECTS – ALL ALTERNATIVES

LOSS OF SOIL WOOD

ALTERNATIVE A – NO ACTION ALTERNATIVE

DIRECT

Under the **no-action Alternative A**, soil wood would continue to accumulate and slowly decay through physical and biological mechanisms. The net trend would be reduced management-derived loss of soil wood. However, no soil or watershed improvement activities would occur, that might accelerate biological recovery in degraded areas, so the long-term upward trend would be slower. If a wildfire occurred, consequent loss of soil wood could range from negligible to severe, depending on location, size, and severity of burn, and removal of dead standing trees associated with salvage logging. Fire could also create standing dead trees that provide recruitment for soil wood over the long term. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition, burning weather, and potential post-fire salvage logging.

The continued accumulation of dead and down fuel loads could contribute to increased potential for wood over extensive areas. Large historic fires burned at 26-69 percent lethality; it is unlikely that any future fire would be outside this wide range, with or without treatment, and loss due to fire is expected to be less than loss due to removal. In general, wildfire effects could often be preferable in large wood cycling and recruitment.

Alternative B

Direct

Potential for loss of large woody debris under **Alternative B** is less than Alternatives C and D, but more than E. Under Alternative B, clear cutting and slash disposal with potential for large woody debris loss would occur on 291 acres.

About 295 acres would be treated in Alternative B with precommercial thinning, shelterwood or group selection harvest in which tree removal is less and/or slash is left on site. The likelihood of excessive soil wood loss is less under these treatments. All of these acres would have more than 50 percent crown removal, but most of that is in smaller diameter classes which would not provide as valuable a soil wood resource as the larger trees left. Of these 295 acres, 61 acres would be underburned. These activities offer good opportunities to retain soil wood in adequate amount and distribution. Excavator piling of slash on the other 234 acres would require stringent oversight to ensure that piling is not excessive.

About 229 acres are proposed for possible roadside salvage of dead and dying trees. Large snags would be left, and the intensity and extent of tree removal would be low.

The 29 acres of soil restoration described under soil compaction and displacement would improve long-term potential for soil wood accrual by accelerating soil stabilization and organic matter development.

Alternatives C and D

Direct

Potential for loss of large woody debris under **Alternatives C and D** are similar, and more than Alternatives B or E. Under Alternatives C and D, clear cutting and slash disposal with potential for large woody debris loss would occur on 356 acres.

About 367 acres would be treated in Alternative C with precommercial thinning, shelterwood or group selection methods in which tree removal is less and/or slash is left on site. The likelihood of excessive soil wood less is less under these treatments. All of these acres would have more than 50 percent crown removal, but most of that is in smaller diameter classes which would not provide as valuable a soil wood resource as the larger trees left. Of these 367 acres, 75 would be underburned. These activities offer good opportunities to retain soil wood in adequate amount and distribution. Excavator piling of slash on the other 292 acres would require stringent oversight to ensure that piling is not excessive.

About 615 acres would be treated in Alternative D with precommercial thinning, shelterwood or group selection methods in which tree removal is less and/or slash is left on site. The likelihood of excessive soil wood less is less under these treatments. All of these acres would have more than 50 percent crown removal, but most of that is in smaller diameter classes which would not provide as valuable a soil wood resource as the larger trees left. Of these 615 acres, 540 would be underburned. These activities offer good opportunities to retain soil wood in adequate amount and distribution. Excavator piling of slash on the other 75 acres would require stringent oversight to ensure that piling is not excessive.

About 227 acres (Alternative C) and 247 acres (Alternative D) are proposed for possible roadside salvage of dead and at risk trees. Large snags would be left, and the intensity and extent of tree removal would be low.

The 40 acres of soil restoration for Alternative C and 46 acres of soil restoration for Alternative D described under soil compaction and displacement would improve long-term potential for soil wood accrual by accelerating soil stabilization and organic matter development.

ALTERNATIVE E

DIRECT

Potential for loss of large woody debris under **Alternative E** is less than any other action alternative. Under Alternative E, clear cutting and slash disposal with potential for large woody debris loss would occur on 75 acres.

About 239 acres would be treated in Alternative E with precommercial thinning, shelterwood or group selection methods in which tree removal is less and/or slash is left on site. The likelihood of excessive soil wood loss is less under these treatments. All of these acres would have more than 50 percent crown removal, but most of that is in smaller diameter classes which would not provide as valuable a soil wood resource as the larger trees left. Of these 239 acres, 35 would be underburned. These activities offer good opportunities to retain soil wood in adequate amount and distribution. Excavator piling of slash on the other 204 acres would require stringent oversight to ensure that piling is not excessive.

About 217 acres are proposed for possible roadside salvage of dead and at risk trees. Large snags would be left, and the intensity and extent of tree removal would be low.

The 102 acres of soil restoration described under soil compaction and displacement would improve long-term potential for soil wood accrual by accelerating soil stabilization and organic matter development.

ALL ALTERNATIVES-

INDIRECT EFFECTS – ALL ALTERNATIVES

Indirect effects of soil wood loss include altered processes of forest regeneration and growth, favoring species requiring lower soil moisture, lower nutrient levels and greater tolerance for potential soil erosion. Indirect effects could also include loss of habitat for species requiring soil wood as dens or substrate for invertebrates, bacteria and fungi, which affect food availability for small rodents and their predators. The relative ranking of likely indirect effects by alternative is (best to worst): A, E, B, C, and D.

IRREVERSIBLE OR IRRETRIEVABLE EFFECTS – ALL ALTERNATIVES

There are no irreversible or irretrievable direct effects due to loss of soil wood, although long-term productivity could be compromised through the age of the next forest stand, until soil wood reserves begin to be replenished.

CUMULATIVE EFFECTS – ALL ALTERNATIVES

Activities that cause repeated loss of soil wood may have cumulative effects on soil porosity, water holding capacity, aeration, biological activity, and long-term productivity, in the case of frequent repeated entries. This is not likely to be a concern for the proposed activities because no areas of harvest are targeted for a second entry.

Activities that result in large areas of depleted soil wood may have cumulative effects at the landscape scale. Past activities considered in cumulative effects are regeneration timber harvest and slash disposal.

Some thinning and pruning have occurred around administrative structures as part of defensible space projects in the analysis area. This work is accomplished by hand. Soil wood was not generally removed, but some snags were removed. Localized potential for cumulative soil wood loss is possible if treatment is continuously sustained.

Repeated harvest and slash disposal in the private lands within the Township have probably affected soil wood regimes.

Foreseeable actions include a proposed 1261 acres of harvest in the Eastside Township project. An estimated25 percent portion of these acres will have high levels of crown removal and may be susceptible to soil wood loss.

With increasing activities in previously unimpacted areas, the spatial extent of soil wood loss is increased, with potential for effects to long-term productivity over larger areas. Rigorous mitigation and restoration may constrain effects to current or improved levels, and develop a long-term upward trend on some previously degraded sites. Cumulative effects are directly related to the scope of regeneration timber harvest. The relative ranking of likely cumulative effects by alternative is (best to worst): A, E, B, C, and D. Wildfire might consume substantial quantities of existing soil wood under any alternative, but would recruit standing dead trees, in the absence of extensive salvage logging.

3.1.2. CROOKED RIVER

EXISTING CONDITION – CROOKED RIVER

INTRODUCTION

The South Fork Clearwater River Landscape Assessment (USDA FS, 1998) identifies "Restore aquatic processes" as the area theme for the lower part of Crooked River watershed, and "Conserve existing aquatic function", as the area theme for Upper Crooked River. The priority for both is very high. Restoration is to include both restoration of aquatic conditions and processes in the watershed, the mainstem channel, and adjustments to the road and trail system to support aquatic restoration and provide for administrative and public uses. Soil resource management affects aquatic processes primarily through erosion, mass wasting, and soil compaction or disturbance that affects subsurface slope hydrology.

GEOLOGY, SOIL DEVELOPMENT, AND LANDFORMS

Rocks weather to form soil parent material; and soil texture, chemistry, and resistance to erosion are highly conditioned by geology.

Geology in the Crooked River watershed is about evenly divided between Belt-age metamorphic rocks (54 percent) and granitics (46 percent). The metamorphics include gneiss, schist, and quartzite that weather to sandy loam, loamy sand, or sand parent materials and develop into soil parent materials that are rated moderate to high for substratum erosion hazard (USDA FS, 1987). They typically weather into soil parent materials that are rated moderate to high for substratum erosion hazard (USDA FS, 1987). These materials typically have low levels of inherent nutrients, and moderate to poor ability to retain nutrients (Garrison and Moore, 1998). Potassium deficiencies noted in these rock types can affect tree growth and susceptibility to root disease.

Granitics are higher in certain nutrients, including potassium, but weather to sandy soils with low ability to retain nutrients. They typically weather into soil parent materials that are rated high to very high for substratum erosion hazard (USDA FS, 1987).

Most soils in the project area (86 percent) have surface layers formed in volcanic ash-influenced loess derived from the eruption of Mt. Mazama about 6700 years ago. This material is physically highly favorable to root growth, being very permeable and with a high ability to hold moisture and nutrients. This material is very easy to compact or displace at any moisture content (Page-Dumroese, 1993), and is essentially irreplaceable without volcanic additions.

Soil response to disturbance depends not only on soil type, but topographic setting and slope hydrology. Landforms have characteristic slope shape, steepness, and stream dissection, which affect erosion and sediment delivery to streams.

- Rolling hills of low to moderate relief occur at lower and mid elevations (14 percent of the watershed). The volcanic ash influenced soil surface layers buffer against erosion except where soil substrata are exposed, as in roads or mines. Substratum erosion hazard is moderate to high. Slopes are gentle to moderate and sediment is delivered to streams with moderate efficiency. Unstable slopes are uncommon, and typically occur as small areas on lower slopes or near stream headlands. West and south facing slopes at low elevation may have thin or mixed ash surface layers. These soils do not hold moisture as well as ash-influenced soils and are more liable to surface erosion.
- Stream breaklands and steep mountain slopes are common in the watershed (37 percent). In comparison to rolling hills, breaklands have steep slopes, shallower soils, thin or mixed loess surface layers, higher surface erosion risk, higher risk of mass failure, and more rapid delivery of sediment to streams. Debris torrents can occur in headwater channels after intense rainstorms or rain-on-snow events.
- Convex slopes are found at upper elevations (42 percent of the area). In comparison to rolling hills, convex slopes have broader ridges, lower drainage density, and bedrock is usually deeply fractured. Volcanic ash surface layers are typically present and buffer against surface erosion. Substratum erosion hazard is high. Slopes are gentle to moderate and sediment is delivered to streams with low efficiency. Unstable slopes are uncommon, and typically occur as small areas on lower slopes or near stream headlands.
- Alluvial valleys form along low gradient stream channels (2 percent of the watershed). Soils are often poorly drained and subject to water transport most of the year. Substrata are coarse sands with gravel and cobble. Some have been dredge mined and only coarse mine spoils remain. Sediment delivery efficiency is very high (USDA FS, 1987); most of this landform is a riparian area.
- Alpine glaciated slopes and till deposits occur at the highest elevations (3 percent of the watershed). These landforms have exposed bedrock or glacial till, and moderate to steep slopes. Substratum erosion hazard is high. Sediment is delivered to streams with moderate to high efficiency. Debris torrents can occur in headwater channels after intense rainstorms or rapid snowmelt.

EXISTING CONDITION – CROOKED RIVER: SOIL PHYSICAL PROPERTIES

SOIL COMPACTION AND DISPLACEMENT

Road building, mining, tractor logging and machine piling have heavily impacted soils in the Crooked River watershed, mostly in lower Crooked River.

Mining effects have been localized but severe: soils in dredge and placer-mined areas have been removed, and sterile tailing piles remain. Soil recovery has been very slow and some of these areas still act as sediment sources (USDA FS 2003). A minimum of 331 acres of this condition occurs in the watershed.

About 3600 acres (8 percent of the watershed) have been tractor logged and/or machine piled resulting in soil compaction and displacement over some of that area. Where the volcanic ash surface layer is compacted, displaced or mixed, soil moisture holding capacity is significantly impaired (USDA FS, 1999b). Early logging practices allowed landings in riparian areas and log skidding was common in draws and down stream bottoms. Some of the units were very large, up to 500 acres in the headwaters of Relief Creek. Tractor logging and dozer piling occurred on sedge meadows resulting in long-term compaction and alteration of stream channels and water tables.

Harvest units that were tractor logged and dozer piled average 52 percent of the activity area damaged in the adjacent Red River watershed (USDA FS, 2003), which has similar landforms and soils. Units that were tractor logged and broadcast burned in that watershed averaged 38 percent damaged (USDA Forest Service, 2003). Units that were tractor logged, but not dozer piled or scarified, sustained 12-42 percent damage. Other monitoring data indicate 15-25 percent damage for this tractor logging without machine piling (USDA Forest Service, 1990 and 1991). Excavator piling has been documented on 92 acres In Crooked River. This is usually less impactive than dozer piling, but can still sometimes result in more than 20 percent detrimental disturbance.

About 981 acres of cable yarding have occurred in Crooked River. Soil damage is usually confined to yarding corridors and landings and accounts for about 4 percent of the activity area, based on monitoring in other areas (USDA FS, 2003).

Road construction also displaces soil, with long-term to permanent impairment of soil productivity. About 567 acres of documented system roads occur where topsoil and subsoil have been displaced, mixed, or lost to erosion. This represents about 1.2 percent of the analysis area.

Motorized and non-motorized trails account for an estimated 28 acres of soil disturbance. Soils are both compacted and displaced. Numerous undocumented user-created ATV trails exist, which add to the amount of detrimental disturbance in the project area.

SURFACE AND SUBSTRATUM EROSION

Past mining has caused locally severe erosion of both surface soil and substrata, often concentrated in valleys where eroded material can reach streams: mainstem Crooked River, Relief Creek, Baker Gulch, and East and West Forks of Crooked River (USDA FS, 1998). A minimum of 331 acres has been affected by dredge mining. Other upland mine sediment sources also exist, where excavation and dozer operations have exposed erodible substrata.

Past fires have resulted in locally severe surface erosion, but post-fire erosion often declines to negligible with vegetation recovery in about 4 years (Megahan, cited in USDA FS, 1981, and Elliot and Robichaud and Brown, 1999 as shown in Elliot and Robichaud, 2001). The most recent large fire occurred in 1945 in the watershed. This fire burned about 5115 acres or 11 percent of the watershed. The largest documented fire in American River occurred in 1889 and burned about 5970 acres, or 13 percent of the watershed. Another large fire burned in 1878. Human ignitions may have been a factor in these fires, but 1889 was a severe fire year throughout the region (Barrett et al., 1997). It is likely that actual burned acres for these early fires were greater, because areas of low and moderate severity fire were often not mapped.

Surface erosion from timber harvest has been slight. The volcanic ash-influenced surface soil is rated as low surface erosion hazard (USDA FS, 1987) and occurs over more than 85 percent of the project area. Excavated skid trails and temporary roads are prone to erosion because the surface soil is removed. About 309 acres have been harvested in the past on soils with high surface erosion potential. These are on steep slopes, usually on south aspects, or in riparian areas where soil is readily detached and transported by water. Harvest has occurred on 832 acres on soils with moderate surface erosion hazard. They are usually on steep slopes on north aspects. Surface erosion on harvest units typically declines to negligible over time, except for some landings, excavated skid trails, and temporary roads that remain on the landscape (USDA FS, 1981).

Documented motorized and non-motorized trails account for 28 acres of soil disturbance, susceptible to surface and subsurface erosion. Twenty acres are on soil substrata rated high for erosion hazard. Numerous undocumented user-created ATV trails exist in addition to the system trails, and add disproportionately to the amount of erosion in the project area, because they may go straight up slopes or cross creeks, and have no erosion controls. They are often gullied or rutted.

Road building is the primary current source of erosion and sediment production in the project area. Seventy six percent of the watershed is rated high or very high for substratum erosion hazard (USDA FS, 1987). About 413 acres of past road construction (about 103 miles) are on soil substrata that are rated high or very high for erosion hazard Road erosion and sediment yield usually decline over time, but continue at a chronic level indefinitely (USDA FS 1981). Periodic large pulses of erosion may occur during intense or prolonged rainstorms or rain-on-snow events, or after burning or harvest that increases water yield and overland flow in interaction with road drainage systems (Wemple, 1994).

Mass Erosion

Mass erosion is the movement of large bodies of soil under the effect of gravity. Movement may be accelerated by high moisture levels, undercutting of toe slopes, or loss of tree rooting strength, among other factors (Chatwin et al., 1991). Landslides here include slumps, creep, debris avalanches or flows, debris torrents, and bedrock slides. Landslides can result in on-site loss of soil productivity, as surface soils are translocated down slope. Sediment delivered to streams may comprise fine sediments, which could have negative impacts, or larger rock and large organic debris, which could enhance stream habitat complexity.

Landslide hazard is low in most (76 percent) of the analysis area. About 3441 acres (about 7.5 percent of the analysis area) are mapped as high hazard for landslides. These are steep slopes, especially in concave headwalls, steep, highly dissected drainage areas, and features that show evidence of past mass wasting. Debris avalanche, debris torrent, and shallow slumps are the most likely kinds of mass failures in the area, but field reconnaissance indicates past mass wasting has been generally restricted to localized events with small to moderate impacts.

Road construction in such settings may precipitate road cut or fill failures, and occasionally loss of the road prism, or, by undercutting a toe slope, activate a landslide upslope. Thirty-four acres (8.5 miles) of road construction and 181 acres of timber harvest have occurred on land rated high for landslide risk. No documented landslide response has occurred on these areas. During the flood episode of 1996-1997, no mass erosion was reported in the analysis area.

Compliance with Forest and Regional Soil Quality Standards

Soil quality standards apply to activity areas other than the dedicated transportation system and administrative sites. This includes temporary roads, harvest units, mine sites, grazed areas, and burned areas. This discussion focuses on Forest Soil Standard number 2: areal extent of detrimental soil disturbance. Refer to the Legal Framework in the Soil Resource section.

About 86 percent of the Crooked River watershed has soils rated highly susceptible to compaction or displacement (Page-Dumroese, 1993; USDA FS, 1987). About 3600 acres have been tractor-logged and 331 acres mined, or 9 percent of the analysis area. Most of this logging occurred from 1960-1989, but extensive clearing occurred during the mining era along mainstem Crooked River and around upland mine sites. About 66 percent of all harvest activity areas have been logged with ground-based equipment. Assuming 80 percent of these would not meet forest Plan standards, (based on sampling in adjacent Red River watershed), 53 percent of all logging areas would not meet Forest Plan Soil quality standard 2, for extent of detrimental soil disturbance on completion of activities. This degree of soil damage is consistent both with other Forest monitoring

(USDA FS 1988, 1990, 1992), and research (Krag, 1991; Froelich, 1978; Davis, 1990, Alexander and Poff, 1985).

Cable logging typically produces relatively little soil damage (research cited in Alexander and Poff, 1985). This is consistent with findings of the Red River watershed assessment, in which a sampled cable-logging unit had sustained 4 percent damage. Additional sampling for the Red Pines project also found another cable unit had sustained less than 4 percent damage. About 981 acres, about 2 percent of the analysis area, has been cable-logged.

Total area of impaired soil quality is estimated at 2225 acres in Crooked River, or 4.9 percent of the watershed.

EXISTING CONDITION – CROOKED RIVER: SOIL CHEMICAL AND BIOLOGICAL PROPERTIES

SOIL POTASSIUM AND NITROGEN LOSS

The inherent rock nutrient status of the local metamorphic gneisses, schists, and quartzites is rated as medium to poor (Garrison and Moore, 1998), but no sampling specific to the analysis area has been done. Their expected soil nutrient status is also medium to low (Buol et al., 1989). These rock types account for about 54 percent of the analysis area. Only 126 acres of YUM yarding (yarding unmerchantable material) or yarding of slash has been documented in the analysis area, on this geologic material. Much of this yarding may have been bole only, but tops and limbs may also have been removed. Removal of tops and limbs is likely to result in about twice as much potassium loss as bole-only yarding, so a few localized areas may have sustained potassium loss.

Granites are rated as having good inherent nutrient status, but medium to low soil nutrient status because of their poor capacity for nutrient retention. Granites account for about 46 percent of the analysis area.

Volcanic ash surface soils have high cation exchange capacity and good moisture storage capacity, but may not have high levels of available soil nutrients, including potassium (Stark and Spitzner, 1982).

Of the tree species likely to be removed, grand fir accumulates the highest foliar levels of potassium, so harvesting tops of this species is more likely to deplete soil potassium than harvesting lodgepole pine tops, which have the lowest levels of foliar potassium (Moore et al. 2004).

Soil nitrogen is typically limiting in all rock and soil types and whole tree yarding has similar or greater effects on soil nitrogen reservoirs (Shaw, 2003). Soil nitrogen can be replenished more rapidly through nitrogen fixation or atmospheric deposition than can potassium, which must weather from rocks.

About 4914 acres, or about 11 percent of the Crooked River watershed, have been clearcut harvested with dozer piling or broadcast burning. Nitrogen losses have probably been substantial on these sites. Because slash disposal burns logs on the ground rather than standing trees, soil temperatures can be hotter and nitrogen loss by volatilization may therefore be greater than with a wildfire.

LOSS OF SOIL WOOD

Coarse woody debris (CWD) is woody material derived from tree limbs, boles, and roots in various stages of decay, here defined as that larger than 3 inches in diameter (Graham et al., 1994). Coarse woody debris protects the soil from erosion, contributes to wildlife and fisheries habitat, and moderates soil microclimate. Highly decayed CWD can hold more water than mineral soil, provides sites for nitrogen fixation, and releases nutrients through decay or burning. Highly decayed wood provides sites for ectomycorrhizal colonization, which contributes to plant growth and plays a role in the food chains of many small rodents and their predators.

Coarse woody debris in natural systems fluctuates with forest growth, mortality, fire, and decay. Harvest and slash burning can remove large wood to a degree that its soil function is impaired, since both standing boles and down wood may be much reduced.

About 4914 acres, or about 11 percent of the Crooked River watershed, have been clearcut harvested with dozer piling or broadcast burning. Most of this harvest was prior to 1990, when the first large woody debris prescriptions might have been implemented. Field reconnaissance in the adjacent Red River watershed indicates large woody debris is deficient on such sites, in comparison to most natural disturbance regimes. In addition, very few green trees or snags were left on regeneration harvest units, so that very few trees are available for recruitment over the next 50-100 years.

Areas of old forest in moist habitats and areas of past mortality of lodgepole pine in the beetle outbreak of the 1980s may have heavy loads of CWD. They are not unnaturally high, but are susceptible to consumption by wildfire. Wildfire would consume some material and create dead standing timber, which would be recruited as large woody debris over time.

ENVIRONMENTAL EFFECTS

Indicators of direct environmental effects on soils are summarized in Table 3.3 below for Crooked River.

Table 3.3: Indicators of Direct Soil Effects by Alternative: Crooked River

Activity	Alternative				
	A	B	C	D	E
Ground-based timber harvest on soils rate high for compaction or displacement hazard (acres) plus acres of new temporary road construction	0	745	729	1020	618
Timber harvest on soils rated high for surface erosion hazard (acres)	0	19	20	20	19
Road construction on soil substrata rated high for erosion hazard (acres)	0	16	20	20	12
Road construction or timber harvest on lands preliminarily mapped as high landslide hazard (acres)	0	11	12	13	10
More than 50 percent canopy removal on geologic materials potentially susceptible to potassium losses (acres)	0	1183	1339	1498	989
More than 50 percent canopy removal that could contribute to nitrogen losses (acres)	0	1319	1472	1726	1114
Clearcut harvest and slash disposal with potential for high soil wood loss (acres)	0	690	748	804	536
Soil restoration on old harvest units (acres). Most are spatially associated with roads to be decommissioned.	0	13	18	23	37
Soil restoration through system road decommissioning (acres)	0	36	39	39	69
Actual acres estimated to sustain detrimental impacts from the proposed actions using Regional Soil Quality definitions of detrimental disturbance, disturbance (20 percent of ground based harvest, 4 percent of cable harvest and 100 percent of temporary road construction)	0	194	201	263	161

Table 3.4: Indicators of Cumulative Soil Effects by Alternative: Crooked River

Activity	Existing Condition Plus Proposed and Foreseeable Actions[1]					
	A	B	C	D	E	Existing Condition
Ground-based timber harvest on soils highly subject to compaction or displacement, road or trail construction, or mining (acres)	4675	5420	5404	5695	5293	4526
Timber harvest or burn on soils rated high for surface erosion hazard (acres)	309	328	329	329	328	309
Road or trail construction on soil substrata rated high for erosion hazard (acres)	433	449	453	453	445	433
Road construction or harvest on lands preliminarily mapped as high landslide hazard (acres)	230	241	242	243	240	215
More than 50 percent canopy removal on geologic materials potentially susceptible to potassium losses (acres), assuming whole tree yarding or YUM yarding of tops	126	1309	1465	1624	1115	126
More than 50 percent canopy removal that could contribute to nitrogen losses (acres), assuming whole tree yarding or YUM yarding of tops; any regeneration harvest	5146	6465	6618	6872	6260	4914
Clearcut timber harvest and slash disposal with potential for high soil wood loss (acres); any regeneration harvest	5146	5836	5894	595	5682	4914
Soil restoration on old harvest units associated with roads to be decommissioned (acres)	0	13	18	23	37	0
Soil restoration through system road decommissioning, assuming road recontour	0	36	39	39	69	0
Actual acres estimated to have sustained detrimental impacts using Regional Soil Quality definitions of detrimental disturbance [2]	2286	2480	2487	2549	2447	2225

[1] A foreseeable action includes Whiskey South project

[2] Estimated conditions of past logging are based on acres tractor-logged multiplied by .35 (the average areal percent damage associated with such tractor logging), plus acres cable logged multiplied by .04 (the average areal damage associated with cable logging) plus documented areas of mine-impacts, system roads, and trails.

Acres by alternative for the American Crooked River project are estimated using the same assumptions except that the percent damage for tractor-logged areas would be held at the Forest threshold (.20).

3.1.2.1. Indicator 1 – Soil Physical Properties

Soil compaction and displacement

Alternative A – no action alternative

Direct

Under the **no action Alternative A**, no soil compaction or displacement would occur as a consequence of road construction, timber harvest, or fuel reduction activities. Existing soil compaction and displacement would persist with very slight natural recovery of surface layers of compacted soils. No soil restoration or watershed improvement activities would occur, so the long-term upward trend would be slow.

If a wildfire occurred, mechanized suppression activities and subsequent salvage logging could create severe soil impacts, depending on fire characteristics and administrative decisions. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition and burning weather. Because the location, intensity and size of future fire, or agency actions in response to fire, are uncertain, with or without implementing any action alternative, the evaluation of alternatives by fire hazard is most appropriately addressed in the Fire section.

The continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe fire effects on soil, including physical alteration of soil structure and development of hydrophobic layers, but compaction and displacement from a potential natural wildfire are not likely.

Alternative B

Direct

Alternative B would result in soil impacts less than Alternative D, but more than Alternatives C and E. Under Alternative B, 728 acres of timber harvest or mechanical fuel reduction would occur using ground-based logging systems on soils highly subject to compaction and displacement and 17 acres of new temporary road construction. Assuming that compaction and displacement can be held to within the 20 percent areal disturbance threshold of Forest Plan Soil standard 2, 177 acres on harvest units would be detrimentally compacted or displaced, along with 17 acres on new temporary roads.

About 514 acres are proposed for possible roadside salvage of dead and dying trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for soil disturbance is slight.

Restoration on existing impacted sites (roads and units) would treat a total of about 49 acres. Existing soil compaction and displacement would be treated on units on an estimated 13 of these acres. Existing roads to be decommissioned account for another 36 of the 49 acres. Temporary roads built for this project would be decommissioned, for an additional 17 acres of restoration.

Alternative C

Direct

Alternative C would result in soil impacts less than Alternatives B and D, but greater than Alternative E. Under Alternative C**,** 704 acres of timber harvest or mechanical fuel reduction would occur using ground-based logging systems on soils highly subject to compaction and displacement, along with 25 acres of new temporary road construction. Assuming that compaction and displacement can be held to within the 20 percent areal disturbance threshold of the Forest Plan Soil Standards, 176 acres on harvest units would be detrimentally compacted or displaced, and 25 acres on temporary roads.

About 502 acres are proposed for possible roadside salvage of dead and at risk trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for soil disturbance is slight.

Soil restoration proposed in Alternative C is slightly more than Alternative B, and less than Alternatives D and E. Restoration on existing impacted sites (roads and units) would treat a total of about 57 acres. Existing soil compaction and displacement would be treated on an estimated 18 of these acres. Existing roads to be decommissioned account for another 39 of the 57 acres.

Alternative D

Direct

Alternative D would result in the greatest soil impacts of any alternative. Under Alternative D, 995 acres of timber harvest or mechanical fuel reduction would occur using ground-based logging systems on soils highly subject to compaction and displacement, along with 25 acres of new temporary roads. Assuming that compaction and displacement can be held to within the 20 percent areal disturbance threshold of the Forest Plan soil quality standard item 2, 238 acres on harvest units would be significantly compacted or displaced, along with 25 acres of temporary roads.

About 541 acres are proposed for possible roadside salvage of dead and dying trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for soil disturbance is slight.

Soil restoration proposed in Alternative D is slightly more than Alternatives B and C, and less than Alternative E. Restoration on existing impacted sites (roads and units) would treat a total of about 62 acres. Existing soil compaction and displacement would be treated on units on an estimated 23 of these acres. Existing roads to be decommissioned account for another 39 of the 62 acres. Temporary roads built for this project would be decommissioned, for an additional 25 acres of restoration.

Alternative E

Direct

Alternative E avoids soil impacts better than any other action alternative, through reduction in road construction and area of ground-based logging. Under Alternative E, 605 acres of timber harvest or mechanical fuel reduction would occur using ground-based logging systems on soils highly subject to compaction and displacement, along with 13 acres of new temporary roads. Assuming that compaction and displacement can be held to within the 20 percent areal disturbance threshold of the Forest Plan soil standard 2, 148 acres on harvest units would be detrimentally compacted or displaced, along with 13 acres of temporary roads.

About 505 acres are proposed for possible roadside salvage of dead and at risk trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for soil disturbance is slight.

Alternative E proposes substantially more soil restoration than any other alternative. Restoration on existing impacted sites (roads and units) would treat a total of about 106 acres. Existing soil compaction and displacement would be treated on units on an estimated 37 of these acres.

Existing roads to be decommissioned account for another 69 of the 106 acres. Temporary roads built for this project would be decommissioned, for an additional 13 acres of restoration.

All Alternatives

Indirect Effects – All alternatives

Indirect effects of soil compaction and displacement include effects to vegetation and hydrologic processes. Compaction and displacement can result in reduced moisture holding capacity, greater drought stress and susceptibility to pathogens or fire. Certain species have a greater competitive advantage in disturbed soils, like weeds or lodgepole pine, so that shifts in plant community composition have been noted in field inventories of harvest units (USDA Forest Service, 2003c). Altered soil porosity and moisture holding capacity (USDA FS 2000) could contribute to higher drought stress, lower ground cover, and shifts in disturbance regimes like erosion or fire. The relative ranking of likely persistent indirect effects by alternative is (best to worst): A, E, B, C, and D.

Irreversible or Irretrievable Effects – All Alternatives

Soil compaction effects can last 70 years (Froelich et al., 1983), but are not irretrievable. Decompaction can at least partly restore soil porosity. Soil displacement that mixes or removes the volcanic ash surface layer reduces soil moisture holding capacity, which may be irreversible without volcanic additions. The relative ranking of likely persistent soil compaction and displacement by alternative is (best to worst): A, E, C, B, and D. Stockpiling and replacing topsoil could mitigate this loss for roads and landings, as well as other mitigation to minimize damage; see the discussion of project design measures and mitigation above.

Cumulative Effects – All Alternatives

Activities that cause soil compaction and displacement may have cumulative effects on soil porosity; water holding capacity, aeration, and long-term productivity, with repeated entries. Cumulative effects may also occur at the landscape level, where large areas of compacted and displaced soil affect vegetation dynamics, runoff, and water yield regimes. About 4526 acres are currently estimated to have sustained detrimental compaction or displacement in the Crooked River watershed due to logging, mining, and road or trail construction. Some thinning, pruning and hazard tree removal have occurred around administrative sites and along road 233 over 24 acres as part of defensible space and hazard tree reduction projects in the analysis area. This work was accomplished by hand with limited machine skidding so ground disturbance was slight. The alternatives will add from 161 to 263 acres, depending on alternative; and the foreseeable Whiskey South project could add an estimated 61 acres due to harvest and road construction, for a total of less than 1 percent of the watershed.

Rigorous mitigation and restoration may constrain these effects to current or slightly improved levels. Additional soil restoration associated with decommissioning of old roads and treating old harvest units will also reduce the extent of cumulative effects within the project area. Cumulative effects are directly related to the scope of timber harvest and mechanical fuel reduction activities, temporary road construction, and soil restoration. The relative ranking of likely cumulative effects by alternative is (best to worst): A, E, B, C, and D. Although Alternative A would not do any soil restoration, most restoration is not completely successful in areas of thin volcanic ash surface soils, so avoidance more successfully conserves soil productivity.

SURFACE AND SUBSTRATUM EROSION

ENVIRONMENTAL EFFECTS

ALTERNATIVE A – NO ACTION ALTERNATIVE

DIRECT EFFECTS

Under the **no-action Alternative A**, surface and substratum erosion processes would continue on roads, skid trails, and landings with slight abatement as slow natural vegetation recovery occurs. Erosion from harvest units would continue to decline to negligible. No new management sources of surface or substratum erosion would occur, so the net trend would be reduced management-derived erosion. However, no soil or watershed improvement activities would occur, so the long-term upward trend would be slow.

If a wildfire occurred, consequent surface soil erosion could range from negligible to severe, depending on location, size and severity of burn, soil disturbance associated with suppression, salvage logging, or burn rehabilitation activities, and interaction of watershed response with the existing transportation system. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition and burning weather.

The continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe burning behavior, which can increase the likelihood of surface erosion, but this may be similar to risks associated with logging and broadcast burning on areas proposed for treatment. Sediment modeling assumptions derived from research (USDA FS 1981) suggest that erosion from tractor logging on gentle to moderate slopes would be slightly less than a severe fire on a steep slope, cumulatively over a 5-year time span, not considering the additional substratum erosion from harvest access roads. Alternative evaluation would depend on the reduction of wildfire size and severity in untreated areas. Refer to the discussion of fire hazard in the Fire management section.

ALTERNATIVE B

DIRECT

Alternative B would result in slight surface erosion and less substratum erosion than Alternatives C and D, but more than Alternatives A and E. Under Alternative B, 19 acres of timber harvest or fuel reduction would occur on soils highly susceptible to surface erosion.

An estimated 16 acres of temporary road construction on soil substrata highly susceptible to erosion are proposed for Alternative B. Road construction is more likely to result in erosion than harvest.

About 514 acres are proposed for possible roadside salvage of dead and at risk trees. This is less than other action alternatives. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for erosion is slight.

The 49 acres of soil restoration described under soil compaction and displacement would reduce surface and substratum erosion problems on some existing sites, particularly on steep skid trails, poorly vegetated landings, and existing temporary roads.

ALTERNATIVE C

DIRECT

Alternative C would result in slight surface erosion and similar substratum erosion to Alternative D, but more substratum erosion than Alternatives A, B and E. Under Alternative C, 20 acres of timber harvest or fuel reduction would occur on soils highly susceptible to surface erosion.

An estimated 20 acres of temporary road construction on soil substrata highly susceptible to erosion are proposed for Alternative C. Road construction is usually more likely to result in erosion than harvest.

About 502 acres are proposed for possible roadside salvage of dead and dying trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential exposure to soil erosion is slight.

The 57 acres of soil restoration described under soil compaction and displacement would reduce surface and substratum erosion problems on some existing sites, particularly on steep skid trails, poorly vegetated landings, and existing temporary roads.

ALTERNATIVE D

DIRECT

Alternative D would result in surface and substratum erosion very similar to Alternative C, but more than alternatives A, B, or E. Under Alternative D, 20 acres of timber harvest or mechanical fuel reduction would occur on soils highly susceptible to surface erosion.

An estimated 20 acres of temporary road construction on soil substrata highly susceptible to erosion are proposed for Alternative D. Road construction is usually more likely to result in erosion than harvest.

About 541 acres are proposed for possible roadside salvage of dead and dying trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for soil erosion is slight.

The 62 acres of soil restoration described under soil compaction and displacement would reduce surface and substratum erosion problems on some existing sites, particularly on steep skid trails, poorly vegetated landings, and existing temporary roads.

ALTERNATIVE E

DIRECT

Alternative E would result in slight surface erosion and less substratum erosion than the other action alternatives. Alternative E would also address more soil restoration that could reduce existing erosion. Under Alternative E, 19 acres of timber harvest or fuel reduction would occur on soils highly susceptible to surface erosion.

An estimated 12 acres of temporary road construction on soil substrata highly susceptible to erosion are proposed for Alternative E. Road construction is usually more likely to result in erosion than harvest.

About 505 acres are proposed for possible roadside salvage of dead and dying trees. Skidding equipment is limited to operating on the road, and steep cut slopes would be protected from damage, so the potential for soil erosion is slight.

The 106 acres of soil restoration described under soil compaction and displacement would reduce surface and substratum erosion problems on some existing sites, particularly on steep skid trails, poorly vegetated landings, and existing temporary roads.

ALL ALTERNATIVES

INDIRECT EFFECTS

Indirect effects of soil surface and substratum erosion include effects to vegetation and hydrologic processes. Surface erosion removes the soil materials with the greatest ability to hold moisture and nutrients, potentially resulting in greater drought stress, poorer growth, and susceptibility to pathogens or fire. Since volcanic ash is not easily replaced, these effects may be very long lasting. Certain species have a greater competitive advantage in eroded soils, like weeds or lodgepole pine, so that shifts in plant community composition and consequent disturbance regimes like erosion or fire, could occur. Eroded surface and substratum material may be delivered to streams and have consequences to water quality, stream temperature, quality of fish habitat, and channel morphology. See the Watershed and Fisheries discussions. The relative ranking of likely indirect effects by alternative is (best to worst): A, E, B, D, and C.

IRREVERSIBLE OR IRRETRIEVABLE EFFECTS – ALL ALTERNATIVES

Eroded surface soil, where it is derived from volcanic ash influenced loess, is irretrievable without volcanic additions. Residual soil materials would develop into topsoil over several decades to hundreds of years, but this material may lack the moisture holding properties of volcanic ash.

The relative ranking of likely surface soil erosion by alternative is (best to worst): A, E, B, C, and D. Effects of eroded substratum material are not irretrievable or irreversible; although effects as delivered sediment may be long lasting.

CUMULATIVE EFFECTS (INCLUDES FORESEEABLE FUTURE ACTIONS)

Activities that result in soil surface and substratum erosion may have cumulative effects on water holding capacity, nutrient pools and retention, and long-term productivity, with repeated entries. Cumulative effects may also occur at the landscape level, where large areas of soil exposed to erosion affect vegetation dynamics, invasive species, runoff, and sediment regimes. Erosion of surface soils on old harvest units is expected to have declined to zero, but substratum erosion from roads continues on about 567 acres in the project area. The alternatives will add from 12 to 20 acres of road construction on soil substrata highly susceptible to erosion, while the foreseeable Whiskey South project does not propose any road construction on highly erodible substrata.

Rigorous mitigation and restoration may constrain these effects to current or slightly improved levels. Control of erosion is generally easier to attain than amelioration of displacement that results in erosion.

Past activities considered in cumulative effects are timber harvest and road construction on soils susceptible to erosion. Mining impacts on at least 331 acres are likely to have resulted in localized severe erosion. Some thinning and pruning have occurred around administrative structures as part of defensible space projects in the analysis area. This work is accomplished by hand, with little soil exposure or likelihood of erosion.

With increasing activities in previously unimpacted areas, the spatial extent of erosion is increased, with potential for effects to on-site productivity, sediment delivery, water yield, and stream morphology over larger areas. Cumulative effects are directly related to the scope of timber harvest and temporary road construction on susceptible soils, and the partial compensation offered by road decommissioning and soil restoration. The relative ranking of likely cumulative effects by alternative is (best to worst): A, E, B, C, and D.

MASS EROSION

ALTERNATIVE A – NO ACTION ALTERNATIVE

DIRECT

Under the **no-action alternative**, mass erosion processes would remain a modest factor in soil processes in the analysis area. Mass erosion from natural causes would continue at small scales and infrequent rates. Mass erosion from past management activities would continue at a localized scale and declining rate as old roads stabilized and harvest units revegetated. No new management sources of mass erosion would occur from these alternatives, so the net trend would be reduced management-derived mass erosion. However, no soil or watershed improvement activities would occur, so the long-term upward trend would be slow.

If a wildfire occurred, consequent mass erosion could range from modest to locally severe, depending on location, size and severity of burn, soil disturbance associated with suppression, salvage logging, or burn rehabilitation activities, and interaction of watershed response with the existing transportation system. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition and burning weather.

However, the continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe burning behavior, which can increase the likelihood of mass erosion in steep draws, drainage headlands, and on steep, wet lower slopes, because rooting strength would be lost, and more moisture available. These effects are similar to clearcut logging and broadcast burning. Alternative evaluation would depend on the reduction of wildfire size and severity in untreated areas, and in areas where partial canopy removal and underburn reduce likely wildfire severity. Refer to the discussion of fire hazard in the Fire section.

ALTERNATIVES B, C, D, AND E

DIRECT

Mass erosion hazard would change slightly from natural rates under **Alternatives B, C, D, and E**. Only 10-13 acres of harvest are proposed under any alternative on lands mapped as high risk for landslides. They will be dropped from harvest if the risk is validated through field review. Less than 1 acre of temporary road construction is proposed on lands mapped as high risk. Road location will be adjusted as needed based on field review to avoid areas of high landslide hazard. Design and mitigation measures address identification of localized areas of significant landslide risk, and adjustment of harvest prescriptions to maintain slope stability.

Soil restoration proposed on existing impacted sites can sometimes address existing mass erosion problems. Activities that include restoration of stream crossings and wetlands on roads, and recontouring roads and temporary roads can treat existing slope failure problems and reduce risk for future failures.

No roads proposed for decommissioning under any alternative in Crooked River are on land mapped as high landslide hazard, but local road and slope failures would be identified and treated as roads are decommissioned.

ALL ALTERNATIVES

INDIRECT EFFECTS – ALL ALTERNATIVES

Indirect effects of mass erosion include effects to vegetation and hydrologic processes. Mass erosion may affect surface or substratum materials. Mass erosion of surface soil removes the materials with the greatest ability to hold moisture and nutrients, potentially resulting in greater drought stress, poorer growth, and susceptibility to pathogens or fire. Since volcanic ash is not easily replaced, these effects may be very long lasting. Certain species have a greater competitive advantage in eroded soils, like weeds or lodgepole pine, so that shifts in plant community composition and consequent disturbance regimes, like erosion or fire, could occur. Typically mass erosion mixes surface and substratum materials so the unique properties of the surface soil are lost. Mass-eroded surface and substratum material may be delivered to streams and have consequences to water quality, stream temperature, quality of fish habitat, and channel morphology. See the watershed and fisheries discussions.

Indirect effects are likely to be slight, and differences among alternatives slight, because of little activity proposed on landslide prone terrain, and the mitigation that would be applied. The relative ranking of potential indirect effects by alternative is (best to worst): A, E, B, and C/D.

IRREVERSIBLE OR IRRETRIEVABLE EFFECTS – ALL ALTERNATIVES

There are no irreversible or irretrievable direct effects of mass erosion, except for potential loss of volcanic ash-influenced topsoil. See the section of effects for surface erosion. Anticipated mass erosion processes under action or no-action alternatives are of slight probability, size, or effects, and are unlikely to exceed natural rates.

CUMULATIVE EFFECTS – ALL ALTERNATIVES

Activities that result in mass erosion are unlikely to have significant cumulative effects in the analysis area because of the low incidence of activities proposed on landslide prone terrain. Rigorous mitigation and restoration may improve the mass wasting condition by road decommissioning, while proposed road construction would be in low hazard locations.

The thinning and pruning that have occurred around administrative structures as part of defensible space projects in the analysis area will not increase mass wasting risk.

Fifteen acres of harvest are proposed on lands mapped as high landslide hazard for the foreseeable Whiskey South project, but no road construction. Field review and development of mitigation measures have reduced the risk of slope failure due to harvest on that terrain to slight.

With increasing activities in previously unimpacted areas, the spatial extent of landslide hazard is modestly increased, with some slight potential for effects to sediment delivery and temporary loss of on-site productivity in localized areas. Cumulative effects are directly related to the scope of past, proposed and foreseeable timber harvest or fuel reduction activities and temporary road construction in susceptible terrain. The relative ranking of likely cumulative effects by alternative is (best to worst): A, E, B, and C/D.

COMPLIANCE WITH FOREST SOIL QUALITY STANDARDS

ALTERNATIVE A – NO ACTION ALTERNATIVE

DIRECT

Under the **no-action Alternative A** the existing condition for compliance with Soil Quality Standards would continue, with slight amelioration as slow natural recovery of compacted surface soil occurred and surface soil development in disturbed areas occurred. Landings, temporary roads, and compacted or excavated skid trails would not recover enough within the temporal bounds of this analysis to meet standards.

No additional lands would be subject to temporary road construction or fuel reduction that would result in soil conditions not in compliance with standards from any of the action alternatives.

However, no soil or watershed improvement activities would occur that might accelerate soil recovery, so the long-term upward trend would be slower in untreated soil restoration areas, than with soil restoration.

If a wildfire occurred, consequent damage to soil conditions from suppression activities, burn severity, or salvage logging could range from negligible to severe, depending on location, size, and severity of burn and subsequent administrative activities.

The continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe burning behavior, but whether this might result in greater or more lasting soil damage than road construction or ground-based logging operations is uncertain. Wildfire seldom results in compaction or displacement, but could result in ground cover loss and erosion that exceeds Forest Plan standards or Regional Guidelines. Evaluation of alternatives depends on being able to compare fire size, location, and severity in untreated areas. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition and burning weather. See the discussion of fire hazard in the Fire management section.

Alternatives B, C, D, and E

Direct

Under **Alternatives B, C, D, and E**, the areas proposed for ground-based timber harvest or mechanical fuel reduction on soils highly susceptible to compaction or displacement, are the areas most vulnerable to exceeding Forest Plan soil standard number 2. The areas proposed for such harvest have no recorded history of harvest or mechanical disturbance in the past, and no evidence of disturbance from aerial photo inspection, and reconnaissance field sampling, and are expected to fully meet either Forest Plan Standards at this time.

Project design and mitigation measures are proposed that constrain equipment type, timing of operation, location and density of skid trails, and restoration of mechanically disturbed areas, with the objective of ensuring that activity areas meet Forest Plan soil standard number 2, upon completion of the proposed activities. These would apply to all alternatives. Because meeting this soil standard is difficult, the relative likelihood of meeting compliance is greater for alternatives that treat fewer acres. The relative ranking of alternatives is (from greatest likelihood of full compliance to least): A, E, B, C, and D.

Additional soil restoration is proposed under Alternatives B, C, D, and E. Recovery of soil physical properties is not expected to be complete on all treated acres, but will establish an upward trend for soil conditions for the treated sites. Activities include decompaction, recontouring, addition of organic matter, weed control, and revegetation to restore compacted and displaced soils on main skid trails, existing temporary roads, landings, and newly constructed temporary roads. The relative ranking of alternatives for soil restoration activities is (greatest to least restoration): E, D, C, B, and A.

All Alternatives

Indirect Effects – All Alternatives

Indirect effects may include alteration of numerous ecological and hydrological processes that may be indirect in time or space. Compaction and soil displacement can affect sediment delivery and water yield that have downstream consequences to water quality and fisheries habitat. Indirect effects to ecological processes include altered plant community establishment, growth and yield, changed competitive advantages to different species, heightened susceptibility to pathogens, drought and fire. Restoration can compensate for some effects, but recovery of full function may not occur in all cases. Based on the feasibility of effecting partial recovery on 1 to 2 percent of areas with past impacts, while incurring 20 percent impacts on new activity areas, the relative ranking of likely indirect effects by alternative is (best to worst): A, E, B, C, and D.

IRREVERSIBLE OR IRRETRIEVABLE EFFECTS – ALL ALTERNATIVES

Soil quality standards address issues of long-term productivity, so failure to comply with these standards implies long-lasting impairment of soil functions, if not irreversible or irretrievable effects. The effects of soil displacement and surface soil erosion are least reversible, and most irretrievable, since the volcanic ash surface material is hard to replace. See those sections. The relative ranking by alternative for these issues is (best to worst): A, E, B, C, and D.

CUMULATIVE EFFECTS – ALL ALTERNATIVES

Activities that cause compaction, displacement, or exposure to erosion, may have cumulative effects on belowground physical and biological processes, hydrologic function, and long-term productivity, especially in the case of repeated entries. Rigorous mitigation and restoration may meet Soil Quality Standards.

Past activities considered in cumulative effects are timber harvest, particularly ground-based logging and dozer piling, and documented mining impacts. Permanent roads are not considered in assessing compliance with soil quality standards. Some thinning, pruning, and hazard tree removal have occurred around administrative sites and along road 233 over 24 acres as part of defensible space and hazard tree reduction projects in the analysis area. This work was accomplished by hand and some limited machine skidding so ground disturbance was slight. Past fires are considered to be recovered and are not considered as cumulative effects.

With increasing activities in previously unimpacted areas, the spatial extent of soil damage is increased. Compliance with standards may be sustained, but incremental effects to long-term productivity over larger areas may occur. Cumulative effects are directly related to the scope of temporary road construction and ground-based logging systems, and the relative compensation by soil restoration. All alternatives may meet Forest Plan soil quality standards if mitigation and design measures are rigorously applied, so that cumulative effects are the same for all alternatives on a site basis, but differ considered additively across the landscape. From this perspective, the relative ranking of alternatives is (best to worst): A, E, B, C, and D.

3.1.2.2. SOIL CHEMICAL AND BIOLOGICAL PROPERTIES

SOIL POTASSIUM AND NITROGEN LOSS

ALTERNATIVE A – NO ACTION ALTERNATIVE

DIRECT

Under the **no-action Alternative A**, soil potassium and nitrogen would continue to cycle at current rates, and not be subject to removal through harvest or prescribed fire. Accrual would continue at low rates from rock weathering, atmospheric deposition, and nitrogen fixation. Soil nutrients would increasingly be bound in organic matter complexes and slowly released through decay. The net trend would be reduced management-derived nutrient loss. However, no soil or watershed improvement activities would occur, that might accelerate biological recovery on degraded sites, so the long-term upward trend would be slower in untreated potential soil restoration areas.

If a wildfire occurred, consequent soil nutrient loss could range from negligible to severe, depending on location, size and severity of burn, loss through salvage logging, and loss of nutrients through erosion or leaching. Fire could also make more nutrients readily available for plant uptake and benefit post-fire plant growth. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition and burning weather.

The continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe burning behavior, which can increase the likelihood of nutrient loss to volatilization, erosion, or leaching. However, whole-tree yarding, hot broadcast burns, or hot burns of machine–piled slash could have equal effects because of the removal of material from the site. Concentration of slash in piles may result in losses due to hotter fires or significant reduction of nutrients from large areas. Alternative evaluation would depend on the reduction of wildfire size and severity in untreated areas, and in areas where partial canopy removal and underburn reduce likely wildfire severity. Refer to the discussion of fire hazard in the Fire section.

ALTERNATIVE B

DIRECT

Potential for potassium loss is less in **Alternative B** than Alternatives C or D, but more than Alternative E. Under Alternative B, potassium levels could potentially be detrimentally reduced on about 1183 acres, where more than 50 percent canopy removal has been prescribed on potentially susceptible geologic materials. Where lodgepole pine comprises most of this removal (about 664 acres of clearcut harvest on metamorphics), potassium loss may be less because this species does not sequester as much potassium as other species. If the material is dead as well, needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, potassium losses could also be minimized.

Potential for nitrogen loss is also less in Alternative B than Alternatives C or D, but more than E. Nitrogen levels would be reduced through timber harvest or mechanical fuel reduction, on 1319 acres where percent canopy removal would be more than 50 percent. Where dead lodgepole pine comprises most of this removal (perhaps as much as 690 acres of clearcut harvest), nitrogen loss may be less because needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, nitrogen losses could also be minimized.

About 514 acres are proposed for possible roadside salvage of dead and dying trees. Intensity and extent of tree removal are limited and tops would be left in the woods, so the potential for nutrient loss is small.

The 49 acres of soil restoration described under soil compaction and displacement would improve potential for nitrogen accretion and retention by accelerating soil stabilization and organic matter development.

ALTERNATIVE C

DIRECT

Potential for potassium loss is less for **Alternative C** than Alternative D, but more than Alternatives B and E. Under Alternative C, potassium levels could potentially be detrimentally reduced on about 1339 acres, where more than 50 percent canopy removal has been prescribed on potentially susceptible geologic materials. Where lodgepole pine comprises most of this removal (about 723 acres of clearcut harvest on metamorphics), potassium loss may be less because this species does not sequester as much potassium as other species. Where the lodgepole is dead as well, needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, potassium losses could also be minimized.

Potential for nitrogen loss is less for Alternative C than Alternative D, but more than Alternatives B and E. Nitrogen levels would be reduced through timber harvest or mechanical fuel reduction, on

1472 acres where percent canopy removal is more than 50 percent. Where dead lodgepole comprises most of this removal (as much as 748 acres of clearcut harvest), nitrogen loss may be less because needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, nitrogen losses could also be minimized.

About 502 acres are proposed for possible roadside salvage of dead and dying trees. Intensity and extent of tree removal are limited and tops would be left in the woods, so the potential for nutrient loss is small.

The 57 acres of soil restoration described under soil compaction and displacement would improve potential for nitrogen accretion and retention by accelerating soil stabilization and organic matter development.

Alternative D

Direct

Potential for potassium loss is greatest for **Alternative D**. Under Alternative D, potassium levels could potentially be detrimentally reduced on about 1498 acres, where more than 50 percent canopy removal has been prescribed on potentially susceptible geologic materials. Where lodgepole pine comprises most of this removal (about 723 acres of clearcut harvest on metamorphics), potassium loss may be less because this species does not sequester as much potassium as other species. Where the lodgepole is dead as well, needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, potassium losses could also be minimized.

Potential for nitrogen loss is greatest for Alternative D. Nitrogen levels would be reduced through timber harvest or mechanical fuel reduction, on 1726 acres where percent canopy removal is more than 50 percent. Where dead lodgepole comprises most of this removal (as much as 804 acres of clearcut harvest), nitrogen loss may be less because needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, nitrogen losses could also be minimized.

About 541 acres are proposed for possible roadside salvage of dead and dying trees. Intensity and extent of tree removal are limited and tops would be left in the woods, so the potential for nutrient loss is small.

The 62 acres of soil restoration described under soil compaction and displacement would improve potential for nitrogen accretion and retention by accelerating soil stabilization and organic matter development.

Alternative E

Direct

Potential for potassium loss is least for **Alternative E**, compared to other action alternatives. Under Alternative E, potassium levels could potentially be detrimentally reduced on about 989 acres, where more than 50 percent canopy removal has been prescribed on potentially susceptible geologic materials. Where lodgepole pine comprises most of this removal (about 522 acres of clearcut harvest on metamorphics), potassium loss may be less because this species does not sequester as much potassium as other species. Where the lodgepole is dead as well, needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, potassium losses could also be minimized.

Potential for nitrogen loss is least for Alternative E, compared to other action alternatives. Nitrogen levels would be reduced through harvest or prescribed fire, on 1114 acres where percent canopy removal is more than 50 percent. Where dead lodgepole comprises most of this removal (as much as 536 acres of clearcut harvest), nitrogen loss may be less because needles and branches are likely to break off during yarding. Where whole tree yarding can be foregone, nitrogen losses could also be minimized.

About 505 acres are proposed for possible roadside salvage of dead and dying trees. Intensity and extent of tree removal are limited and tops would be left in the woods, so the potential for nutrient loss is small.

The 106 acres of soil restoration described under soil compaction and displacement would improve potential for nitrogen accretion and retention by accelerating soil stabilization and organic matter development.

All Alternatives

Indirect Effects – All Alternatives

Indirect effects of loss of soil nutrients include reduced growth and yield, increased susceptibility to pathogens (like root infection), and shifting species composition as species with ability to sequester nutrients (like grand fir) out compete species less able (like larch), (Garrison and Moore, 1998). The relative ranking of likely indirect effects by alternative is (best to worst): A, E, B, C, and D. Wildfire could affect any alternative by resulting in volatilization, leaching or erosion loss of nutrients, but also by making more nutrients readily available for plant uptake.

Irreversible or Irretrievable Effects – All Alternatives

There are no irreversible or irretrievable direct effects of nutrient loss, except for potential loss of potassium. Recovery of soil potassium depends on slow inputs from rock weathering and may represent an irretrievable loss in the case of whole tree yarding of green trees, especially grand fir, or hot broadcast burns on clearcuts, on susceptible geologic substrata. The actual potassium status of these rock types has not been locally assessed. A possible mitigation measure beyond minimizing whole tree yarding is fertilization. Nitrogen is replenished more rapidly through biotic and abiotic fixation, but may also have long-lasting effects. The relative ranking of likely potassium and nitrogen loss by alternative is (best to worst): A, E, B, C, and D.

Cumulative Effects – All Alternatives

Activities that cause soil potassium and nitrogen loss may have cumulative effects on soil productivity, plant growth and yield, susceptibility to pathogens, and successional processes, with repeated entries. Past effects to potassium reserves due to management are not thought to be significant, because no entry into areas with prior timber harvest is proposed. Rigorous mitigation and restoration may constrain effects to current or slightly degraded levels for potassium, and little long-lasting effect for nitrogen.

Some thinning and pruning have occurred around administrative structures as part of defensible space projects in the analysis area. This work is accomplished by hand. Lower branches and small trees were generally removed, and either hand piled and burned. Localized potential for cumulative soil nutrient loss is possible, if treatment is continuously sustained.

Foreseeable actions include an estimated 363 acres of timber harvest or mechanical fuel reduction as part of the Whiskey South project. No whole tree yarding is proposed. A mix of treatments is proposed for slash disposal, with perhaps 232 acres likely to be machine piled, which could contribute to redistribution and volatilization of potassium and nitrogen.

With increasing area of activities in previously unimpacted areas, the spatial extent of likely nutrient loss is increased, with potential for effects to landscape composition, structure, and function.

Cumulative effects are directly related to the scope of past, proposed and foreseeable regeneration timber harvest, particularly whole tree yarding, and likelihood for piling and burning slash that results in significant nutrient redistribution and volatilization. The relative ranking of potential cumulative effects by alternative is (best to worst): A, E, B, C, and D. Wildfire may result in significant potassium and nitrogen loss under any alternative, but may also result in greater net nutrient availability.

LOSS OF SOIL WOOD

ALTERNATIVE A – NO ACTION ALTERNATIVE

DIRECT

Under the **no-action Alternative A**, soil wood would continue to accumulate and slowly decay through physical and biological mechanisms. The net trend would be reduced management-derived loss of soil wood. However, no soil or watershed improvement activities would occur, that might accelerate biological recovery in degraded areas, so the long-term upward trend would be slower. If a wildfire occurred, consequent loss of soil wood could range from negligible to severe, depending on location, size and severity of burn, and removal of dead standing trees associated with salvage logging. Fire could also create standing dead trees that provide recruitment for soil wood over the long term. The scope of such impacts is not foreseeable, given the uncertainties of fire ignition, burning weather, and potential post-fire salvage logging.

The continued accumulation of dead and down fuel loads could contribute to increased potential for locally severe burning behavior, which can result in loss of existing soil wood, while at the same time recruiting new potential soil wood. However, fuel reduction activities, hot broadcast burns, or hot burns of machine–piled slash could have equal effects because of the removal of wood boles from. Concentration of slash in piles may result in losses due to hotter fires or significant reduction of large wood over extensive areas. Large historic fires burned at 26-69 percent lethality in the adjacent Red River watershed; it is unlikely that any future fire would be outside this wide range, with or without treatment, and loss due to fire is expected to be less than loss due to removal. In general, wildfire effects could often be preferable in large wood cycling and recruitment.

ALTERNATIVE B

DIRECT

Potential for loss of large woody debris under **Alternative B** is less than Alternatives C and D, but more than E. Under Alternative B, clear cutting and slash disposal with potential for large woody debris loss would occur on 690 acres.

About 807 acres would be treated in Alternative B with precommercial thinning, shelterwood or group selection harvest in which tree removal is less and/or slash is left on site. The likelihood of excessive soil wood loss is less under these treatments. All of these acres would have more than 50 percent crown removal, but most of that is in smaller diameter classes which would not provide as valuable a soil wood resource as the larger trees left. Of these 807 acres, 441 acres would be underburned. These activities offer good opportunities to retain soil wood in adequate amount and distribution. Excavator piling of slash on the other 366 acres would require stringent oversight to ensure that piling is not excessive.

About 514 acres are proposed for possible roadside salvage of dead and dying trees. Large snags would be left, and the intensity and extent of tree removal would be low.

The 49 acres of soil restoration described under soil compaction and displacement would improve long-term potential for soil wood accrual by accelerating soil stabilization and organic matter development.

ALTERNATIVE C

DIRECT

Potential for loss of large woody debris under **Alternative C** is less than Alternative D, but more than Alternatives B or E. Under Alternative C, clear cutting and slash disposal with potential for large woody debris loss would occur on 748 acres.

About 826 acres would be treated in Alternative C with precommercial thinning, shelterwood or group selection methods in which tree removal is less and/or slash is left on site. The likelihood of excessive soil wood less is less under these treatments. All of these acres would have more than 50 percent crown removal, but most of that is in smaller diameter classes which would not provide as valuable a soil wood resource as the larger trees left. Of these 826 acres, 497 would be underburned. These activities offer good opportunities to retain soil wood in adequate amount and distribution. Excavator piling of slash on the other 329 acres would require stringent oversight to ensure that piling is not excessive.

About 502 acres are proposed for possible roadside salvage of dead and dying trees. Large snags would be left, and the intensity and extent of tree removal would be low.

The 57 acres of soil restoration described under soil compaction and displacement would improve long-term potential for soil wood accrual by accelerating soil stabilization and organic matter development.

ALTERNATIVE D

DIRECT

Potential for loss of large woody debris under **Alternative D** is greater than any other alternative. Under Alternative D, clear cutting and slash disposal with potential for large woody debris loss would occur on 804 acres.

About 1164 acres would be treated in Alternative D with precommercial thinning, shelterwood or group selection methods in which tree removal is less and/or slash is left on site. The likelihood of excessive soil wood less is less under these treatments. All of these acres would have more than 50 percent crown removal, but most of that is in smaller diameter classes which would not provide as valuable a soil wood resource as the larger trees left. Of these 1164 acres, 582 would be underburned. These activities offer good opportunities to retain soil wood in adequate amount and distribution. Excavator piling of slash on the other 582 acres would require stringent oversight to ensure that piling is not excessive.

About 541 acres are proposed for possible roadside salvage of dead and dying trees. Large snags would be left, and the intensity and extent of tree removal would be low.

The 62 acres of soil restoration described under soil compaction and displacement would improve long-term potential for soil wood accrual by accelerating soil stabilization and organic matter development.

ALTERNATIVE E

DIRECT

Potential for loss of large woody debris under **Alternative E** is less than any other action alternative. Under Alternative E, clear cutting and slash disposal with potential for large woody debris loss would occur on 536 acres.

About 754 acres would be treated in Alternative E with precommercial thinning, shelterwood or group selection methods in which tree removal is less and/or slash is left on site. The likelihood of excessive soil wood loss is less under these treatments. All of these acres would have more than 50 percent crown removal, but most of that is in smaller diameter classes which would not provide as valuable a soil wood resource as the larger trees left. Of these 754 acres, 404 would be underburned. These activities offer good opportunities to retain soil wood in adequate amount and distribution. Excavator piling of slash on the other 350 acres would require stringent oversight to ensure that piling is not excessive.

About 505 acres are proposed for possible roadside salvage of dead and dying trees. Large snags would be left, and the intensity and extent of tree removal would be low.

The 106 acres of soil restoration described under soil compaction and displacement would improve long-term potential for soil wood accrual by accelerating soil stabilization and organic matter development.

ALL ALTERNATIVES

INDIRECT EFFECTS – ALL ALTERNATIVES

Indirect effects of soil wood loss include altered processes of forest regeneration and growth, favoring species requiring lower soil moisture, lower nutrient levels and greater tolerance for potential soil erosion. Indirect effects could also include loss of habitat for species requiring soil wood as dens or substrate for invertebrates, bacteria and fungi, which affect food availability for small rodents and their predators. The relative ranking of likely indirect effects by alternative is (best to worst): A, E, B, C, and D.

IRREVERSIBLE OR IRRETRIEVABLE EFFECTS – ALL ALTERNATIVES

There are no irreversible or irretrievable direct effects due to loss of soil wood, although long-term productivity could be compromised through the age of the next forest stand, until soil wood reserves begin to be replenished.

CUMULATIVE EFFECTS – ALL ALTERNATIVES

Activities that cause repeated loss of soil wood may have cumulative effects on soil porosity, water holding capacity, aeration, biological activity, and long-term productivity, in the case of frequent repeated entries. This is not likely to be a concern for the proposed activities because no areas of harvest are targeted for a second entry.

Activities that result in large areas of depleted soil wood may have cumulative effects at the landscape scale. Past activities considered in cumulative effects are regeneration timber harvest and slash disposal.

Some thinning and pruning have occurred around administrative structures as part of defensible space projects in the analysis area. This work is accomplished by hand. Soil wood was not generally removed, but some snags were removed. Localized potential for cumulative soil wood loss is possible if treatment is continuously sustained.

Foreseeable actions include a proposed 363 acres of harvest in the Whiskey South project. An estimated 232 acres will have high levels of crown removal and machine piling, and may be susceptible to soil wood loss.

With increasing activities in previously unimpacted areas, the spatial extent of soil wood loss is increased, with potential for effects to long-term productivity over larger areas. Rigorous mitigation and restoration may constrain effects to current or improved levels, and develop a long-term upward trend on some previously degraded sites. Cumulative effects are directly related to the scope of regeneration timber harvest. The relative ranking of likely cumulative effects by alternative is (best to worst): A, E, B, C, and D. Wildfire might consume substantial quantities of existing soil wood under any alternative, but would recruit standing dead trees, in the absence of extensive salvage logging.

CONCLUSIONS

EXISTING CONDITION – AMERICAN RIVER

- The analysis area is dominated (96 percent) by surface soils derived from volcanic-ash influenced loess that is highly susceptible to compaction and displacement, and whose favorable moisture and nutrient holding properties are critical to long-term productivity. These surface layers are relatively thin and it is hard to decompact them without mixing with underlying infertile substrata. Soil substrata include both highly erodible (42 percent) and moderately erodible (58 percent) materials.
- Detrimentally compacted and displaced soil conditions are widespread in the watershed due to past mining, ground-based logging and dozer piling, and road construction. These conditions are primarily associated with harvest units (about 19 percent), system roads (about 1.4 percent), and localized mine sites (about .5 percent). In addition, the major meadows (.6 percent) have long been grazed, farmed, or otherwise impacted and are expected to have sustained detrimental soil disturbance.
- Soil substratum erosion from a dense road network contributes to instream effects.
- Landslide hazard is dominantly low (.6 percent of the area is rated as high risk) and incidence of mass wasting is infrequent, small in scale, and localized in effects. Areas of Tertiary sediments within the Elk City Township are prone to localized road cut failures, because of their stratified materials that perch water.
- Geologic materials thought to be susceptible to potassium loss are widespread in the watershed (85 percent). Nutrient losses, including potassium and nitrogen, are expected to have occurred in areas of regeneration harvest (10 percent of the watershed), especially where whole tree yarding or intensive slash disposal has occurred.
- Soil wood regimes have been interrupted on large areas (14 percent of the watershed) due to regeneration harvest and slash disposal with little provision for retaining existing soil wood or providing for soil wood recruitment by leaving live and dead trees.
- An estimated 58 percent of past timber harvest activity areas do not meet Forest Plan soil quality standards. Percent of detrimental soil disturbance is expected to range from 20 to 80 percent on units that have been tractor logged and dozer piled based on similarity to Red River watershed conditions.
- Widespread lodgepole pine mortality will result in locally heavy accumulations of down wood. This may result in locally severe fire effects to soils in the case of wildfire under

severe burning conditions. These potential fire effects are within the historic range of variability for soils in these fire regimes.

EXISTING CONDITION – CROOKED RIVER

- The analysis area is dominated (86 percent) by surface soils derived from volcanic-ash influenced loess that is highly susceptible to compaction and displacement, and whose favorable moisture and nutrient holding properties are critical to long-term productivity. These surface layers are relatively thin and it is hard to decompact them without mixing with underlying infertile substrata. Highly erodible materials dominate (76 percent) soil substrata.
- Detrimentally compacted and displaced soil conditions are common in the watershed due to past mining, ground-based logging and dozer piling, and road construction. These conditions are primarily associated with harvest units (about 8 percent), system roads (about 1.2 percent), and localized mine sites (a minimum of .7 percent).
- Soil substratum erosion from roads, mines and trails contributes to instream effects in lower Crooked River.
- Landslide hazard is dominantly low (7.5 percent of the area is rated as high risk) and incidence of mass wasting is infrequent, usually small in scale, and localized in effects.
- Geologic materials thought to be susceptible to potassium loss are common in the watershed (54 percent). Nutrient losses, including potassium and nitrogen, are expected to have occurred in areas of regeneration harvest (11 percent of the watershed), especially where whole tree yarding or intensive slash disposal has occurred.
- Soil wood regimes have been interrupted on large areas (11 percent of the watershed) due to regeneration harvest and slash disposal with little provision for retaining existing soil wood or providing for soil wood recruitment by leaving live and dead trees.
- An estimated 56 percent of past timber harvest activity areas do not meet Forest Plan soil quality standards. Percent of detrimental soil disturbance is expected to range from 20 to 80 percent on units that have been tractor logged and dozer piled based on similarity to Red River watershed conditions.
- Widespread lodgepole pine mortality at low and mid elevations will result in locally heavy accumulations of down wood. This may result in locally severe fire effects to soils in the case of wildfire under severe burning conditions. These potential fire effects are within the historic range of variability for soils in these fire regimes.

SUMMARY OF ENVIRONMENTAL CONSEQUENCES – AMERICAN RIVER/CROOKED RIVER

- **Soil physical properties** and compliance with Forest Plan soil standards would be most affected by temporary road construction and use of ground-based mechanical harvest systems.
- Surface soil loss from roads through displacement and mixing with infertile substrata has long lasting consequences for soil productivity, because of the superiority of the volcanic ash surface layer over subsoils and substrata. Road decommissioning will only partially recover soil productivity.
- Soil compaction and displacement on ground-based logging units may be dispersed widely, slow to naturally recover, and difficult to restore because the ash surface material is relatively thin and restoration methods may be constrained by technology or economic

considerations. Most of the project area soils have shallow topsoil over sterile subsoil, which will require careful decompaction to avoid mixing (Andrus and Froelich, 1983).

- Relative ranking of alternatives for soil physical properties is (best to worst): A, E, B, C, and D.
- Mitigation measures for compaction, displacement and erosion include:
  1. Layout and marking to avoid wet areas and unstable slopes (all alternatives)
  2. Increased skid trail spacing
  3. Suspension of logs where cable systems are used
  4. Moisture controls on operations
  5. Using old skid trails where possible
  6. Stockpiling and re-use of topsoil
  7. Minimizing excavator piling where feasible
  8. Controls on slash piling equipment
  9. Minimizing excavator piling in favor of burning wherever feasible
  10. Controls on extent and intensity of piling
  11. Decommissioning of new temporary roads
  12. Main skid trail and landing decompaction and recontouring.
  13. If areas of past soil damage exceeding the Forest Plan standard number 2 were identified in the course of layout, areas would be dropped from harvest or activities modified to remain within the standards.

  These measures could reduce effects for all harvest alternatives to meet Forest Plan standards for detrimental disturbance upon completion of activities, but the relative ranking would remain.
- Mitigation for burning includes developing burn boundaries and prescriptions to avoid ignition in wet areas, and controlling burn intensity through timing and burning weather.
- Mitigation measures for mass erosion include field review of potential units to identify areas of significant landslide risk, and treatment through avoidance. Areas of moderate landslide risk would be mitigated as needed through adjustment of basal area removal, attention to site-specific leave tree marking, and controlling burn severity in slash treatment.
- Wildfire under any alternative would not likely result in extensive compaction, displacement, or substratum erosion, except as a consequence of fire suppression activities and potential subsequent salvage logging. Surface soil erosion would likely increase in areas of steep slopes with hot burns.
- **Soil chemical properties** would be most affected by activities that result in excessive loss of nutrients where there is the potential for whole tree yarding, machine piling and burning, and clear cutting with potentially hot broadcast burns. Relative ranking of alternatives for soil nutrient loss is (best to worst): A, E, B, C and D.
- Mitigation through leaving adequate tops and branches on the harvest area, keeping slash piles small and dispersed, minimizing machine piling, and minimizing hot burns could reduce effects and the differences among alternatives.

- Wildfire under any alternative could affect nitrogen regimes through volatilization, erosion, or leaching loss or through chemical transformation making existing nitrogen more available for plant uptake. Potassium is less susceptible to volatilization losses.
- **Soil biological properties** could be most affected by activities that result in high levels of loss or redistribution of existing coarse woody debris, and recruitable coarse woody debris (snags and green trees). This potential is greatest where clear-cut harvest and slash disposal occur. Relative ranking of alternatives for potential coarse woody debris loss is (best to worst): A, E, B, C, and D.
- Mitigation through snag, green tree, and down wood retention as described in the mitigation section could reduce effects and the differences among alternatives to negligible levels.
- Wildfire under any alternative could materially affect coarse woody debris regimes through both consumption and recruitment.
- **Soil restoration activities** are planned as part of the watershed improvement activities, as part of harvest impact mitigation on new units, restoration on some old units, and will also accrue as a consequence of decommissioning of existing and new temporary roads.
- Soil restoration would consist of decompaction, recontouring, stabilization for erosion control, application of organic matter, revegetation, and weed control as needed.
- Soil restoration can potentially improve infiltration, improve water and nutrient regimes, restore more natural water yield regimes, reduce likelihood of runoff events, reduce potential for weed invasion, stabilize slopes, and improve tree growth and vegetation establishment. Luce (1997) indicates about a 50 percent increase in hydraulic conductivity when a road is ripped, over an unripped road, but this is still less than half the conductivity of an undisturbed forest soil. Sanborn et al. (1999a) show reductions in bulk density and carbon increase in soils treated with decompaction, topsoil amendment and organic matter incorporation. Plotnikoff et al. (1999) found that decompaction with a winged subsoiler and revegetation improved tree growth on landings. Sanborn et al. (1999b), summarized soil restoration work in British Columbia, and concluded that topsoil stockpiling and reuse, as well as tillage, and adding organic matter and nutrients, resulted in greatest restoration of soil productivity. Foltz and Maillard (2004) demonstrated that recontoured roads were less likely to experience runoff and soil loss than roads not decompacted and recontoured, but still had lower infiltration rates than natural forested slopes.
- Alternatives that maximize soil restoration and minimize new soil disturbances achieve the greatest level of soil resource protection and restoration. Using these criteria, the relative ranking of alternatives is (best to worst) A, E, B, C, and D. Alternative A is somewhat problematic, because neither restoration nor impactive management activities are proposed. However, it is a lot easier to avoid damage than to undo it, so this alternative is ranked higher than the action alternatives.
- Treatments typically address less than 3 percent of each old tractor-logged unit because dispersed areas of soil damage are often hard to access and treat without compounding soil resource damage.

SUMMARY OF CUMULATIVE EFFECTS – AMERICAN RIVER/CROOKED RIVER

SOIL PHYSICAL PROPERTIES AND COMPLIANCE WITH FOREST PLAN STANDARDS

SOIL COMPACTION AND DISPLACEMENT

- Cumulative effects due to soil compaction and displacement include altered soil porosity; water holding capacity, aeration, and long-term productivity. Effects are in proportion to the past, proposed and foreseeable area impacted by ground based logging, mining, and road construction. The relative ranking of cumulative effects by alternative is (best to worst): A, E, B, C, and D for both watersheds. The total percent of each watershed with long persistent soil damage under the past, proposed and foreseeable actions is 9-10 percent for American River and 5-6 percent for Crooked River. The no-action Alternative A results in the least soil damage in each watershed. Alternative E results in the least cumulative soil damage of the action alternatives in each watershed.

SURFACE AND SUBSURFACE EROSION

- Cumulative effects due to increased erosion include reduced water holding capacity, nutrient pools and retention, and long-term productivity, and altered vegetation dynamics, as well as instream effects of sedimentation. Effects are in proportion to the past, proposed, and foreseeable area impacted by road building and mining on erodible substrata, and, to a lesser extent, harvest on erodible surface soils. The relative ranking of cumulative effects by alternative is (best to worst): A, E, B, C, and D for both watersheds. The total percent of each watershed with long persistent soil erosion under the past, proposed and foreseeable actions is about 2.7 percent for all alternatives in American River and 1.6-1.7 percent for Crooked River. The no-action Alternative A results in the least soil erosion in each watershed. Alternative E results in the least cumulative soil damage of the action alternatives in each watershed.

MASS EROSION

- Cumulative effects due to mass erosion may include loss of more fertile topsoil, delivery of large and fine sediment, rock, and woody debris to streams, loss of investments such as roads or culverts, and shifts in plant community composition. Effects are in proportion to the past, proposed and foreseeable area impacted by landslides in response to road building and timber harvest on landslide prone terrain. All alternatives avoid entry into areas of high landslide hazard. Cumulative effects are expected to be negligible for American River, and slight and in proportion to the miles of road construction and timber harvest on moderately susceptible terrain in Crooked River. The relative ranking of cumulative effects by alternative for Crooked River is (best to worst): A, B/E, and C/D.

COMPLIANCE WITH FOREST AND REGIONAL SOIL QUALITY STANDARDS

- Activities that cause compaction, displacement or exposure to erosion may have cumulative effects on belowground physical and biological processes, hydrologic function, and long-term productivity. All alternatives may meet Forest Plan soil quality standards on harvest units, if mitigation and design measures are rigorously implemented, so that cumulative effects are the same for all alternatives on a site basis. The likelihood of exceeding the standards increases with increasing number of activity areas proposed for ground based logging or temporary road construction. Temporary roads are not considered part of the permanent transportation system, but are difficult to restore to former productivity. Cumulative effects occur with repeated entries or additive entries in a watershed. From this perspective, the relative ranking of alternatives for both watersheds is (best to worst): A, E, B, C, and D. The no-action Alternative A results in the greatest likelihood of compliance in each watershed. Alternative E results in the greatest likelihood of compliance of the action alternatives in each watershed.

Soil Chemical and Biological Properties

Soil Potassium and Nitrogen Loss

- Activities that cause soil potassium and nitrogen loss may have cumulative effects on soil productivity, plant susceptibility to pathogens, and successional processes. Cumulative effects are in proportion to the scope of past, proposed and foreseeable regeneration timber harvest, particularly whole tree yarding, and likelihood for piling and burning slash that may result in extensive nutrient redistribution and volatilization. Geologic materials potentially susceptible to potassium loss are widespread in American River and common Crooked River. The scope and location of whole tree yarding are uncertain. No second entries into areas of past harvest are proposed so repeated withdrawals of potassium and nitrogen is limited to past natural fires. Potential for cumulative effects is ranked on the extent of regeneration harvest. From this perspective, the relative ranking of alternatives for both watersheds is (best to worst): A, E, B, C, and D.

Loss of Soil Wood

- Activities that cause repeated or widespread loss of soil wood may have cumulative effects on soil porosity, water holding capacity, aeration, biological activity, and long-term productivity. Repeated entries are not an issue for the proposed action, but activities that result in large areas of depleted soil wood may have effects at the landscape scale. Rigorous mitigation and restoration may minimize effects. The relative ranking of potential cumulative effects is in proportion to the area of regeneration timber harvest and slash disposal and is (best to worst): A, E, B, C, and D.